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Volume II.

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Leipzig

1890

Translated by H. Clifford Bloxam, B. Arch.

Emeritus Professor of Architecture

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M A N U A L

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G O T H I C C O N S T R U C T I O N

by

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V. THE CHURCH IN CROSS SECTION AND ELEVATION.

1..Single-aisled church and single-aisled choir.-

Proportions of the height of the interior.

In the development of the cross-section of the church from the general form of plan are first to be considered the requirements of the vaulting, those of the introduction of light and the endeavor for a perfected architectural expression in the interior and on the exterior. For a church with a single aisle it is possible for all to become suitable at the same time without special difficulty.

To the vaults may always be opposed external abutments sufficiently strong, even with very great thrusts, it is only for r reasons of economy, which also in single-aisled churches indicate the limiting of the mass of the vaults and abutments. Light may be intriduced through side wallu in sufficient abundance, and no great restraints are laid on the artistic form; it can move quite freely in the development of the details and elso in fixing the main proportions.

The proportion of the height of the whole and of the different parts quite strongly influences the character of the architectural structure. Consideration of mediaeval works also allows here the recognition of an infinite diversity. Indeed is expressed in the buildings of different countries in the dimensions of the heights a certain relationship, but this is subject to a change in its divisions of time, and in special cases is broken through by the endeavor for the development of greater magnificence and higher elevation.

On the average the height experienced an increase in the course of centuries, which abouh held an equal pace with the enlargement of the window surfaces and the restriction of the masses of the walls. Yet at all times beside those proud and lofty works also appear those of quite modest height, since the building materials at command here exerted important influences.

Heights of the springing of the vault and the crown.

The first requirement is indeed that the height of the springing of the vault (h in Fig. 827) and also the height of the c crown (H) is in an intelligible ratio to the width, in other words that the form of the cross section cut through the cross vault is pleasing to the eye.

Certainly the effect of this cross section also depends on a certain dependence on the length of the entire interior as well as that of a single bay, the elevation of the vault, the arrangement of the windows; it can notable affect the happy proportions by the influences of this kind.

This length of the entire church is so far influential, since for small lengths the height should also not be too important, and so as to make the general view of the vault still intelligible to the eye, the height should never be more than half the length. Concerning a choir adjoining the church, the length of the nave natwrally comes in consideration.

If one desires to make a difference between churches with small, medium and great height of the nave, the limits can be drawn as follows:-

A church is to be termed low, when the springing od its vaults is raised above the floor less than the width of the nave (h : b lessthan 1), or which amounts to about the same, whose total height to the crown remains less than 1 1/2 times the width of the nave. Here belong many chapels and numerous little village churches, but also many large single-aisled churches, that on account of great span of their vaults rise to an important height. In many village churches the springing of the vault lies at about the height of the head or even lower, while the crown of the vault scarcely attains a height equal to that of the clear width of the span. As an example among many may serve the little church of the village of Volksen near Einbect belonging to middle Gothic, which with a span of about 6 m shows a height of the springing of 1.8 m and a height of crown of not 5 m. With this small height it has only two short bays and a triangular choir ending, so that its effect is not at all too depressed.

A mean height results if the springing of the vault is 1 to 1 1/2 times the width of the nave, or the crown of the vault is 1 1/2 to 2 1/2 times the width. Very many small and large churches of the Romanesque and Gothic periods, whose interiors make a particularly interesting impression, remain within these limits, and also the quite slender effect of the upper story of S. Chapelle at Paris does not exceed these proportions in height.

As slender must be termed a single-aisled churcth if the proportion of height exceeds the limits just indicated, but the

height of the springing of the vault seldom rises above twice the span of the vault, and the height of the keystone oves 2 1/4 times the width of the nave. The middle aisle of churches with several aisles, which has a certain relation to the total width,and which Besides must often be extended high on account of the introduction of light, averages higher than the nave of the simple church, often exceeding three times the width (Cologne).

Geometrical relation between height and width.

If one seeks satisfactory geometric relations between height and width, especially between the height of the springing of the vault (h in Fig. 827), and the clear width b (the latter being understood as in the clear between the projections, or measured between the planes of the side arches or the face of the wall), then can the following exist.

1. Height = half width (h = 0.5b).

2. Height = half diagonal of square of width (h = 0.707 b). This ratio appears among others to occur in the church of S.Maria Selspritsch in Carinthia, and in the choir of the church at Volksmarsen belonging to the early Westphalian group.

3. Height = width (h = b). Choir of Early Gothic church, Late Gothic S. Martin's church at Cassel and the longitudinal aisle of many other churches.

4. Height = diagonal of square of width (h = 1.4142 b). Choir of S. Elisabeth at Marburg, S. Severi at Erfurt, church at Immenhausen in Hesse, nave of S. Chapelle in Paris, etc.

5. Height = 1 1/2 times width (h = 1.5 b). Choir of church at Friedberg.

6. Height = twice the span (h = 2 b). S. Maria at Mühlhausen.

The information preserved by F. Lacher (Reichensperger, Mixed Writings) goes frnm hhe total height to the crown of the vault, and requires for this 1 1/2 times the width (which he terms the right height), or even 2 or 3 widths. Lacher further fixes the rise of the vault, when he makes the diagonal arches semicircles and gives equal heights to the cross and side arches. In the l last precept the treatise mentioned calls such a vault a correct vault.

The roof of the singleAaisled church.

The outer wall above the vaults has no further problem to satis fy than to bear the beams and framework of the roof. Accord-

Accordingly on most Romanesque and Gothic buildings it is only carried so high that the roof beams extending over the vaults rest on it, and even in bending by accident loads do not touch the outer surfaces of the compartments. For this purpose usually suffices a space of 10 to 30 cm.

Passing over the attic floor.

Beneath each pair of rafters may lie a beam, so that the average distance between them is only about 1 m. In this case it is easy to make the attic floor passable by logs laid on them or also by a closed flooring. But convenient travel over the floor is usually so little required, that men are unwilling to employ a complete series of beams. Therefore in ancient and modern times they often use through beams only where required to resist the thrust of the roof, and then have distances of 2.5 to 5 m or even more. If in such a case it is desired to make the attic floor passable for use, they may larger logs or even small beams be laid across it, but heavy loads are then to be avoided.

Frequently the beams are not utilized at all, but the vaults are directly used for passing through the attic, and then the beams can be placed so high that one can go beneath them or are arranged at greater distances just above the vaults, so that t they do not hender passage

A higher location of the beams is made possible in theee ways.

Raising the beams.

1The external walls are carried so high, that one can pass under the beams lying on them. The partial walls produced thereby can give a desirable overload for the side aisles and also favor the development of a dignified main cornice on the exterior. Such an elevation above the height of the head is however seldom found (Rheims), but it is somewhat more common that men are satisfied to raise the beams 1 to 1 1/2 m above the vaults, so that in p passing over these it is necessary to bend at every beam.

2. To save masonry the walls are not continued up in their entire thickness, but only as a thin wall lying behind the gutter parapet (Fig. 829).

3. The beams are placed higher in the construction of the roof. (Fig. 830). The wall then ends directly over the side aisles, the rafters standing on little ties laid on the wall plates. For the length of the rafters not to bend under the collar beams an-

anchoring them, there are added the struts d and braces c. Such a construction is found in S. Blasien in Mühlhausen. Yet more firmly is held the foot of the rafter py the framework indicated in Fig. 831, where the beam is better replaced by ties.

Roof framework with a smaller height of wall.

A higher position of the beam, solely on account of the passage over the vaults, however belongs to the exceptions, since it must be purchased by a greater quantity of masonry or a less reliable combination of the roofs, it occurs far more frequently that the outer wall is made as low as possible to save masonry. Particularly very strongly raised vaults frequently rise into the attic, while the tiebeams only pass through above the l lower cross arches,or even roof framework in the mode of Figs. 830 and 831 is employed, which then has a greater justification.

Isolated trussed beams.

When merely isolated beams pass through, the intermediate short blocks are prevented from displacement by the rafters. To lay them on the wall merely fastened to it is not proper, since a transfer of the thrust of the roof to the wall is quite undesirable (as shown on p. 163 et seq., the wind pressure striking on the opposed half of the roof is sufficient to create a portion transferred through the roof). Therefore the thrust of the blocks would be led to the through beams, which can be done by special cross beams or even by the wall plate. If the cross beams are long (a in Fig. 832), they are prevented from bending by small braces b or by horigontal little diagonals c. A lack of braces in construction always causes that the rafters must always connected by fastenings to resist tension. Therefore in the middle ages the wall plates were more generally utilized to transfer the thrust, when deeply gained into them. For small distances between the main beams there sufficed two broad wall plates without other aids, but for greater distances between b beams two struts were placed between the wall plates (Fig. 833), or as represented in Fig. 833 a representing the roof framework of the church of S. Nicolai at Reval.

Some statements concerning beams and roof framework will be given later in the description of hall churches. An exhaustive representation of the extremely varied mediaeval roof combinations must remain for separate treatment, but here it man at least

be indicated that in the middle ages the extreme waste of timber of later centuries was unknown, that men avoided ends of timbers with insecure fastenings, especially for parts in tension, and preferred indents or splices of moderate depth, even when certain tiebeams must extend obliquely.

The covering of the roof extends over so far, that the water drops directly from it (Fig. 834) or by a wash is carried to a drip of the main cornice, in case no gutter is provided. (Further see p. 362 and later under Cornices).

Reduction of thickness of wall upward.

Reasons for small reductions.

The external wall of a single-aisled church or choir, likewise the wall of the hall church or of the side aisle of the basilica, rises not entirely or nearly equalthickness from the ground to the main cornice. The Romanesque churches only show a slight p projection at the base, while the Gothic also mostly exhibits a slight offset at the height of the window sill moulding.

It may appear surprising, that the external increase of thickness downward was not carried farther in order to approxemate as nearly as possible to the ideal form of resistance (Fig. 343). But this would certainly have occurred if men had to do with resisting a uniform thrust of a vault; but now occurred besides that also varying stresses, especially under the influence of the wind. The wind pressure in the wall struck by it is opposed to the thrust of the vault, it may in many cases even be greater than the latter and therefore strive to incline the wall inward. The opposite wall will also receive a part of the wind pressure through the framework of the roof and in some cases through the crown of the vault (see below). But the higher that a side force is applied, so much the less is it possible to reduce the thickness of the wall upward. In the limiting case with only a great horizontal that strikes the top of the wall rising with the same thickness and without overload, the danger of overturning would be equally great above each bed joint from the bottom to the top. Even for the upper courses would occur the possibility of sliding, that would vanish for the lower part of the wall (in which again the compression is greater under the influence of the masonry loading it). This limit indeed does not exist for the wall of a church, since a certain overload exists and the great thrust

of the cross vault acts far below in the springing of the vault, moreover from the preceding it would appear that the diminishing of the wall could not be carried too far on account of the effect of the wind. Particularly then if the buttresses are already strongly diminished, so much the more occasion is there to leave the wall full above, and indeed this can even be required to m make the wall thicker above wide windows, as will be proved somewhat later.

The resistance of the walls to the thrust of the vaults is treated on p. 137 to 152, and as opposed to the wind pressure on p. 163 to 165. Since no examples of calculations are given there, let two of them be interpolated here as illustrative.

Example 1. Investigation of the stability of a single-aisled church without buttresses, with and without the effect of the wind. Fig. 835. The church has 10 m clear width with 6 m length of bays, and 20 m height of wall above the plinth and internal floor. It is vaulted with cross vaults of porous bricks 1 brick thick with a rise of 2/3 measured crossvise, and the abacus lies 13 m above the floor. Each wall space is opened by a window 2.8 m wide and averaging 13 m high above the sill course 4 m from the floor, the part of the wall under the window has blind arches and must be regarded as not adding strength of it. Otherwise the wall of sandstone weighs 2200 kil per cu. m., with a thickness of 1.5 m below the sill course and of 1.4 m above it.

Forces H and V of the vaults. On a wall space rests half a vault with an area of 6 × 5 = 30 sq. m. According to p. 135 IV c each sq. m. area on plan exerts a horizontal thrust H_0 = 180 kil and a load on abutment of V_0 = 530 kil; thus for the vault, H = 30 × 180 = 5400 kil, and V = 30 × 530 = 15900 kil. The intersection of the vault thrust with the face of the wall can be assumet at 1.6 m above the capital or 14.6 m above the floor.

Weight of the wall. The volume of the lower part of the wall weighs Q_1 = (6.0 - 2.8) × 1.5 × 4.0 × 2200 = 42240 kil. The upper part of the wall above the sill course weighs Q_2 = (6.0 × 16.0 - 2.8 × 13.0) × 1.4 × 2200 = 18356 kil Together $Q_1 + Q_2$ = 225808 k.

Weight of roof. For 90 kil per sq. m. of roof surface with f framework and slate covering (p. 162) each half of the roof weighs 8.0 × 9.4 × 90 = 5076 kil = D. As vertical component of wind load for about 50° inclination according to Table on pa 163; on the windward side = 6.0 × 9.4 × 23 = 1297 kil; on leeward side =

$$\eta' (1 - 0.75) + (\eta_2 (1 - 0.75) + \gamma \chi = \chi \times 11.5.$$

χ for η_2, η_2, γ and χ have already been mentioned under
theory, where is assumed $\chi = 0.60$.

Then the compression-ratio at 0.80 = from the known χ and
η' = from the theoretical relation to the mentioned value of
the wall 1.80 x table, we have it also at the edge of the wall-
ls thus.(Then).

The mechanical work of the part of the wall considered becomes
the wingtip contains to $1.80 \times 0.80 = 1.80$ kg. m = [illegible] kg.
The wall must cause the load = $\eta_1 + \eta_2 + \gamma = 58300$ kil to bound
movement, or = 0.7000 kil. if the most loss is added. The average
[illegible] on the other side is twice as much, thus above 13 kil.
[illegible] of the lower wall.

6.0 × 9.4 × 35 = 1974 kil. Adding these to the weight of the r roof gives for the windward side 6373 kil = D; on the leeward side D″ = 7050 kil.

The horizontal wind thrust of the roof according to Table on p. 168 amouts to 6.0 × 9.4 × 69 = 3892 kil. The distribution of this thrust on the two walls can be determined, it may be assumed that the windward side receives S′ = 1892 kil and on the leeward side S″ = 2000 kil.

Wind pressure against the wall. With regard to protecting adjacent buildings, let the wind be neglected on the lower 4 m in height, but on the upper part of the wall 14 m high is taken the full pressure of 120 kil per sq. m. Then the wind pressure amounts to 6.0 × 16.0 × 120 = 11520 kil with its centre of application at 12 m high.

In this case the wall will be most strongly stresses in the bed joint above the plinth, and it therefore will be limited to the investigation at the cross section.

A. Compression above the plinth without wind. For an unknown point of intersection by the resultant compression, which lies at X m from the internal face of the wall, there is established the equation of moments of all forces acting on the wall panel. (See on this Fig. 371 on p. 140).

$$Q_1 (X - 0.75) + Q_2(X - 0.70) + V X = H \times 14.6.$$

If for Q_1, Q_2, V and H are substituted their numerical values above, then is computed X = 0.99 m.

Thus the compression occurs at 0.99 m from the internal face and 0.51 m from the external surface in the horizontal area of the wall 1.50 m thick, so that it lies at the edge of the middle third.(Kern).

The horizontal area of the part of the wall considered between the windows amounts to 1.50 × 3.20 = 4.80 sq. m = 48000 sq cm. On this area rests the load = $Q_1 + Q_2 + V$ = 242000 kil in round numbers, or = 247000 kil if the roof load is added. The average compression accordingly = $\frac{247000}{48000}$ = 5.2 kil per sq. cm. The compression at the outer edge is twice as much, thus about 10 kil. The compression diminishes upward in the wall, but will be distributed below over a larger area by the rapid widening of the plinth of the lower wall.

B. Wind pressure on the wall struck by the wind. To the preceding are added the forces D′, S′ and W; the equation of moments

$$\frac{1}{2}\rho(X - 0.75) + \frac{1}{2}\rho(X - 0.75) + \frac{1}{2}\rho X \times 11.8. \qquad X = 1.16 \text{ m.}$$

Height of envelope between $Y = 12.3 \times 1.0 \times 1.4 \times$ [illegible]

$$+ \frac{1}{2}\rho'(Y-0.70) + \frac{1}{2}\rho'(Y-0.70) + \rho'(Y-0.70) \times 12 \times 18.3 =$$

$$\frac{1}{2}\rho'(Y - 0.70) + \frac{1}{2}\rho'(Y - 0.70) + \rho'(Y-0.70) \times 18.3 \times$$

$$+ \frac{1}{2}\rho'(Y-0.70) + \rho'(Y-0.70) \times 18.3 + \rho' \times 20. \qquad Y = 1.11 \text{ m.}$$

is established in the same manner for the unknown pivot, which is X′ m. from the internal surface of the internal surface of the wall.

$Q_1(X' - 0.75) + Q_2(X' - 0.70) + VX' + D'(X'-0.70) = H \times 14.6 - W \times 12.0 - S' \times 20.0$. Substituting the given numerical values, there results:- $X' = 0.27$ m.

While usually the compression lies nearest the outer face, under the effect of the wind it recedes to near the inner face (nearly to 1/6 the thickness) and produces there a compression that nearly equals four times the average compression (p. 144 and Table on p. 145), thus amounting to about 20 kil per sq cm.

C. Compression in the leeward wall. There act the forces Q_1, Q_2, V, H, D″ and S″, for which the equation of moments for the pivot X″ from inside of wall is:- $Q_1(X'' - 0.75) + Q_2(X''-0.70) + V X'' + D''(X''-0.70) = H \times 14.6 + S'' \times 20$. $X'' = 1.14$ m.

The compression recedes to 0.36 m from the outer edge, and there produces a compression at the edge of about 15 kil sq cm.

Stability of a wall with buttresses.

Example II. Investigation of the same wall assuming a thinner wall with larger windows and with buttresses.

The wall is 1 m thick and is opened by great windows, that with the wall beneath them have an average height of 17 m and a width of 4.5 m. The buttresses are 18 m high and 1 m thick, projecting 1.5 m below and 0.70 m above, thus 1.10 m as an average from the wall, their centre of gravity lying 0.57 m outside the external face of the wall and 1.57 m from the inner face.

Weight of wall = Q = (6.0 × 20 − 4.5 × 17.0) × 1.0 × 2200 = 95700 kil (= 43.5 cu. m).

Weight of projecting buttress = P = 18.0 × 1.0 × 1.1 × 2200 = 43500 kil (= 19.8 cu. m.

A. Compression above plinth without wind pressure. There is again sought the equation of moments for the pivot at the centre of compression lying at the unknown distance X from the inner face of the wall.

$Q(X - 0.5) + P(X - 1.57) + V X = H \times 14.6$. $X = 1.26$ m.

For the horizontal area of the buttress and the supporting part of the wall = 3.0 sq. m or 30000 sq. cm, the average compression is computed at 5.4 or 5.2 kil per sq. cm, according as the roof load is added or not. For the already calculated location of the compression, that remains inside the kern, the com-

compression at the outside edge is about 8 or 9 kil per sq cm.

B. Compression in the windward wall. Corresponding to the preceding:-

$Q(X' - 0.5) + P(X' - 1.57) + V X' + D'(X' - 0.5) = H \times 14.6 - W \times 12.0 - S \times 20.0.$ $\quad X' = 0.14$ m.

C. Compression in leeward wall.

$Q(X'' - 0.5) + P(X'' - 1.57) + V X'' + D''(X'' - 0.5) = H \times 14.6 - S'' \times 20.0.$ $\quad X'' = 1.47$ m.

At the leeward wall the line of support is thus more than 1 m from the outer edge, so that the latter receives a compression not much over 10 kil per sq. cm. On the contrary at the windward side the pressure at the edge would rise to about 50 kil per sq. cm. (Then according to p. 144 only the area of 3 × 14 = 42 cm wide, thus for 1.5 cm length with an area of 0.64 sq. m takes part in the transmission of the compression. Since the load amounts to about 162000 kil, there comes 22.5 kil per sq. cm as the average, and the compression at the edge would be twice as great, thus being = 51 kil). If the wall alone existed, there would occur with good construction a not exactly dangerous stress, but one always much exceeding the allowable amount (20 to 25 kil per sq. cm for good sandstone in cement). But now is found an adjustment between the stresses in both walls, for neither wall is so rigid, that it does not bend somewhat before the wind, and the windward and more strongly stressed wall yields more than the other and consequently leans more at top against the vaults, and by this and also the roof beams transfer a part of its side forces to the other wall, until both are nearly stressed equally. Thereby in both walls the compression attains about the same magnitude. If in this manner about 1/4 or 1/5 of the wind pressure is transferred to the other side, so that the centre of pressure below moves about 20 cm, it is then at the windward side about 34 cm and at the leeward side about 167 cm from the internal surface, whereby the edge compression is reduced to about 20 kil per sq. cm and results somewhat smaller at the opposite side.

It also shows that in thick walls of not only a basilica, but also already in any similar church must be possible a reciprocal bracing of the upper part of the wall, whether this be by the crown of a vault, the cross arches or the roof beams. Moreover such effects of wind occur very rarely and often not in decades.

The more common winds of moderate pressure make unnecessary an upper transfer, as they will mostly even rather lessen the edge pressure than increase it in the windward wall. Seldom will the pressures in the preceding example much exceed 10 to 12 kil per sq. cm.

Comparison of volume of the wall with and without buttresses.

In both examples the stress in the masonry seems about equally great for erection with or without buttresses, but the solid w wall requires about 1 1/2 times the volume. By a still greater reduction in thickness of the wall and increased size of window with a contemporary shortening of the pier even more volume can be saved, there are limits drawn here. So far as the wall lies under the side arches may it be resolved entirely into the window and the plank wall beneath, assigning its task to the pier, but the side arch above alwans retains its great statical importance, that is here the more important, the more the masonry is otherwise restricted.

The side arch and the masonry above it.

Task of the side arch aod the masonry on it.

Besides the buttress, the side arch and the masonry over it is the most important part of the supporting masonry. The tasks of the side arch and of the upper masonry are so varied, that they require close consideration. They have to:-

1. Connect the adjacent buttresses in the wall plane.
2. Receive the thrusts acting in the parts of the upper vaults (particularly for raised vaults).
3. Bear the roof load.
4. Transfer the wind thrust against the roof and the upper p part of the wall to the buttresses.

Bracing in the plane of the wall.

Bracing in the wall plane is the more necessary, the more are to be expected forces acting longitudinally from various great thrusts, effects of wind, various settlements, etc., and the m more the remaining width of the wall is reduced by a wide window, the higher is the wall and the narrower are the buttresses.

The wall above the side arch forms an immovable shape restricted by the inclination of the buttresses, and certainly it is required that over the crown of the window shall remain a sufficiently strong portion of the wall to resist displacement in the manner of Fig. 836. If the window must rise very high, then

a gable can strengthen this part.

Below the window sill course the portion of the wall connecting the buttresses again forms a strong longitudinal stiffening. If this part is resolved into blind windows, at least a strong connection over at and under the window is advisable, that of itself results from the arrangement of a passage of this height.

There remains only the possibility of a bending of the buttresses at the height of the window as in Figs. 837 and 837 a. W With a smaller height of the window neither is to be feared, and with a very considerable height a later horizontal division of the window is made by a passage, as found in S. Elisabeth's church at Marburg. It is particularly in place in single-aisled choir and transepts of tall basilicas, in which a division in height is otherwise given by the adjacent parts with several aisles. Very high windows are accessible with difficulty and a are easily unsatisfactory in effect, and thus the long windows like stilts in the transverse aisle of some churches in Mecklenburg are almost disturbing.

Reception of the thrust of the vault.

2. The thrust of a vault is borne by the side arches for swelled and raised vaults, and it is shown on p. 50 et seq. how its probable magnitude is obtained. But an ordinary cross vault with straight ridge can also exert a thrust on the upper part of the side arch, when by the mode of construction, crushing or other accidents, the stresses are guided in this direction (p. 47). Now certainly in such a cross vault the side arches avoid these stresses by a very slight yielding, and then all parts of the vault without necessarily endangering its strength must seek its support in the regular way from the ribs and springings. Such a transposition of the pressure usually does not occur without small cracks or crushing, and it is therefore well for the side arches to be sufficiently stiff to resist in a certain degree such accidental effects. Greater external forces (wind and the like) that may be transferred to the side arches by the vaults will very soon be treated particularly.

Reception of the roof load.

The distribution of the roof load depends on the kind of roof framework. If a purlin roof is employed, whose main trusses rest on the buttresses, then the intermediate trusses will load the side arches but little, but if all trusses are alike, then the

weight is continuously distributed over the entire length of w wall. The vertical loads of the roof, that are usually small in comparison to the weight of the masonry, rarely injure the side arches, and therefore are rather desirable than heavy. It is otherwise with the sidewise forces that the roof framework may transfer to the wall. Aside from the wind (see below), they may be produced by a defective resistance of the thrust, in case of collar beams placed higher (Figs. 830, 831), or braced (Figs. 832, 833). Strong thrusts from the roof should ever be prevented in a structure by a proper choice of the roof connections, since alreadn the unavoidable sidewise movements by the wind at this height suffice to create.

Reception of the wind thrust.

4. The wind thrust against the roof and walls can for the wall over the side arch be more important than all preceding influences. The wind pressure against the roof is to be resolved into a vertical wind load and a horizontal wind thrust (Table on p. 163). The first is added to the roof load and like that is more useful than injurious. The horizontal wind thrust whose magnitude is given in the last column of the Table on p. 163, must be received by one or the other wall or by both; how it is divided between the two sides is not generally to be said.

If the roof framework occurs with a strong beam under each t truss (Fig. 838), the roof in itself forms an unchangeable figure, which the wind seeks to thrust sidewise in its entire form. The friction of the beam or plates on the level top of the wall hinders a sliding of the roof (anchors are usually unnecessary for the friction is generally sufficient with a free bedding). But if the roof cannot slide on the masonry, it would seek to press this over, so that the entire wind thrust finally acts on the walls.

If both walls are equally resistant, then will about equally take part in the thrust, perhaps the wall receiving the greater vertical load will also have more thrust. On the contrary if one wall be less stable in consequence of its form or of other forces already thrusting it sidewise, the weaker wall will already yield somewhat after it has received a small part of the thrust, and then the greater portion must be transferred through the beams to the other resistant wall (Fig. 838 a) where the weak wall is represented as a hinged support, clearly illustrating

this). A strong series of roof beams can even transfer a part of this wind pressure against the wall to the other side, but then is to be an anchoring of the beams to the wall and a good securing of the upper part of the wall against overturning, sliding and bulging is to be kept in mind. The thin parts of walls usual in parapets (Fig. 829) are then unsuitable.

If instead of the full series of beams only braces or collar beams exist (Fig. 830), then the roof framework is less able to transfer the wind thrust to the stronger wall, and the weaker wall must chiefly take its part on itself, and it can only relieve itself by the interposition of a stiff vault below it.

For purlin or trussed roofs the wind pressure comes to act in the trusses, and these are placed above the buttresses carried sufficiently high, so that the movements of the wind can be kept away from the intermediate wallu. But if division in bays requires an intermediate main truss above the crown of the side arch, this is the more exposed to the movements.

When the wall exposed to the wind is not sufficiently stable to receive the thrust of the wind (see p. 167 to 169 concerning the basilica of Example II, p. 337, in regard to single-aisled churches), a part of it must be transferred to the other wall, which is made possible by a stiff cross arch (Fig. 413) or the ridge of the vault (Fig. 412). If the vault cannot make a greater transmission of pressure (for example a light tunnel net vault without cross arches), then in case of need as just stated, the roof beams must lend themselves to stiffen it.

Among these effects of forces against the clearstory wall are naturally most important the sidewise forces produced by the vaults or the wind, for slender basilicas with thin piers the thrusts may gather in their upper walls, that equal or even exceed the regular thrusts existing in the springing od the vault. In single-aisled hall churches or those with several aisles, t they must never be underestimated. Example II, p. 337, gave to the leeward side a wind thrust of about 5000 kil transmitted by the roof and the ridge of the vault, which thus is even not much below the vault thrust of 5400 kil acting lower down.

Under these forces may the upper courses of the wall be either moved, or the masonry above the buttresses may be inclined, or finally the wall may bulge between the buttresses.

Sliding of the upper courses.

A slipping of the upper courses may most easily occur if the building is already struck by a great storm before the mortar is hardened, and before the stiffening vaults are turned. The exposed wall, so far as it cannot itself master it, seeks to g guide it to the other side by means of the framework of the roof, whereby the roof beams or together with the upper courses of masonry may be slipped. Where it seems to be required, this danger can be prevented by a preparatory stiffening of the wall and by anchoring the framework of the roof and also the upper courses of masonry together (stone or metal dowerl).-If the mortar is hardened, a sliding of the courses is no longer to be feared, so long as over each joint the vertical load is 1 1/2 to 2 times as great as the horizontal force.

To the wind thrust against the roof should usually correspond a sufficiently great roof load, as in the example on p. 336 a thrust of 3892 kil, that could act on a roof in the most unfavorable cases, while the roof load for this wall would amount to 7050 kil. But if a greater wind thrust against the wall is to be transferred through the ridge of the vault, then maw the vertical load be shown as too small. It is then to be increased by making the wall thicker or higher in its entire length above the vault, or by adding gables at the dangerous points, when instead of stiffening, i.ea, transferring the wind pressure through the ridge of the vault, this is not possible through the cross arch to a point somewhat lower.

Overthrow of the upper part of the wall.

The overturning of the upper part of the wall may occur, when for thin walls the buttresses (or flying buttresses on basilicas) are not extended sufficiently high, or if the depths of the buttresses is diminished too much upward. The stability can easily be investigated, when for the bed joints above the buttresses or over their offsets, the curve of pressure is sought in the usual manner (see p. 140).

Bending of the upper wall outward.

A bending of the wall between the buttresses is to be feared, when the buttresses are sufficiently high and strong, but the wall is too thin. With stiff cross arches will the wall exposed to the wind be most affected by bending, (Fig. 413), but with stiff ridges of the vault it will be more the leeward wall (Fig. 412). For the exposed wall it is less to be feared, since it

leans against the vault compartments and can support itself through these against the opposite wall or in an oblique direction against the stiff cross arch. On the contrary for the leeward wall bulging outward is vern easily possible, since there the wind thrust is added to the perhaps already existing thrust acting in the ridge of the vault.

The behavior of the wall under the forces bending it outward may be explained by Figs. 839 and 839 a. One cannot count on a resistance to bending in the horizontal plane of the wall, as occurs in a beam in question, since the masonry can be assigned no tensile stresses, and the wall can only offer resistance in this case by its horizontal ability to support, i.e., by the possibility of developing a line of support in its ground plan. This line of support is best assumed, so that it passes within the middle third (thus $c = \frac{d}{3}$). The lines of support of two adjacent bays join at the point P and there produce a force to be received by the buttress, which equals the sum of all thrusts acting on the length of the bay. If one also desires to know how great is the force D acting in the curve of support, then is established for half a bay the equation of moments for the point P, which is $D\ c = R\ a$, in which R is the resultant if all thrusts acting in half the vault. The greatest edge pressure at the point B is found when $d = \frac{2}{F} D$, where F = the cross section in sq. cm of the resisting masonry here above the crown of the aide arch

The line of support drawn in the plan in Fig. 839 a must not be conceived to lie in a horizontal plane; while it gradually moves outward from G to P, it at the same time moves downward as shown in the elevation (Fig. 839). The greater the weight of the wall in comparison to the thrust, so much the more rapidly does the line pass downward. One can assume about $\frac{e}{c} = \frac{Q}{S}$, when Q = weight of a side arch load and S = sum of the thrusts coming above on a bay. From this simple relation may be approximately calculated the height of the point P, thereby determining how high must be extended the buttresses. In Example II, p 387, the weight Q is computed at about 48000 kil, and the thrust S in the most unfavorable case at 5000, c at 0.33 m (= 1/3 thickness of wall), and thereby e results = $\frac{0.33 \times 48000}{5000}$ = 3.2 m. The point P to which at least the buttress is to be carried would thus be about 3 to 3 1/2 m below the eaves.

The greater the side forces acting on the upper part of the

wall, and the smaller the weight of the wall above the side arches, the higher must the buttress extend. For basilicas the point of application P_2 may attain such a high location (it is to be found in the way just given), that the ending of the flying buttresses close beneath the eaves may be imperatively neeessary.

That the wall with the forces acting on it both horizontally and vertically may safely bear on the buttresses, a good joining of the stones by indenting or if necessary, also by mechanical aids is important. That men did not overlook this requirement also in earlier times is shown among other things by the relieving arches, which have often been added over the apexes of the windows of the wall, as at Amiens, Troyes and the S. Chapelle in Paris.

Treatment of the upper part of the wall.

It it is demonstrated above in what way are to be provided t the requirements in the upper part of the wall, it is now asked how these are to be justified. There is an entire series of different solutions to follow, indeed occurring in many old examples, whose prencipal members may be stated here.

1. The wall has small windows and no buttresses, it is so thick from bottom to top, that it safely resists the horizontal forces acting everywhere at different heights.

2. The wall has windows of moderate size and moderately wide buttresses. The buttresses have only to resist the thrust of the vaults at the height of the springing. All other forces the wall itself can resist, it being sufficiently thick from b bottom to top to be sufficiently safe from overturning.

3. The windows open from buttress to buttress, to which all side forces must be led. Side and window arches are combined, the wall is made thicker over the side arches for better stiffening rekuired in the case, either externally by the projection of the arch mouldings from the sides of the buttresses, or inside by corbelling out over the vaults.

4. The side arch is moved inward, between it and the window wall is inserted a tunnel arch, otherwise being as before. This treatment most naturally occurs by projecting the pier inside.

5. The upper load is increased by gables. The gables by their weight prevent from sliding or inclination of the upper courses of the wall, they bring the line of support (Fig. 839) in accordance with the pointed form of the side arch, strengthen its

crown by high windows, Fig. 836. The heavier theload of the gable, the thinner may either be the wall over the windows, or t the lower may the buttresses stop.

6. So far as possible, all forces would be directly led to t the buttress, that is carried very high, on the other hand is kept as far as possible from the wall bay. This will be attained by suitable construction of the roof (for example a purlin roof with main trusses over the buttresses), by a corresponding form of vault (not thrusting at the ridge), and particularly by the use of a stiffened cross arch (Fig. 413), that forms a closed transverse connection from a buttress to lying opposite.

By the last method is the mass of the wall most effectively reduced, even so far that the side arches as in the churches of Burgundy from the Early Gothic (Fig. 848) make themselves entirely independend of the external wall. But entirely aside from this astonishing boldness, it is always advantageous to a church both in regard to the economy of masses made possible thereby, as very particularly on account of the less mobility of the parts concerned, to transfer all side forces if possible to the cross arches and buttresses.

On the whole the six modes of execution mentioned represent a graduated series from harder to easier construction, and further intermediate steps may be inserted, since certain ones may be joined together with good results.

On the architectural treatment of the upper part of the wall, see later under Gables, Cornices etc.

The lower part of the wall.

The form and treatment of the cornice is treated farther below in a special section, for the general cross section of the church only its height and projection comes into consideration come into consideration. Usually the external wall has three cornices, the simply profiled projection of the plinth in one or two divisions at the height of the internal floor or the internal cornice continuing beneath the window parapet, usually a cap moulding crowning the offset of the wall, and the main or eave cornice occupying the first place on account of its architectural and practical importance.

Wide projections of cornices, so far as practically valuable can be simply constructed with the materials at hand, are allowed by mediaeval art within proper limits, but usually it does

not give to the cornice that unlimited predominance like antique art or the Renaissance. In any case they avoided aiding storms by too great projectinns, or to even afford opportunities to the architect for the execution in the before mentioned materials.

To give general rules on the distance of the projection is not possible, since also here practical and artistic considerations may occur in manifold relations. The late time certainly has also sought to arrange these members in a general scheme.

In Lacher the difference between the half thickness of the wall and the half diagonel of the same is given as the measure of the projection of all cornices, so that thus a b c in Fig. 841 gives the profile of the cap extending around below the windows (sill moulding) and a e b c is that of the roof coroice. The s same mode of determining dimensions is also found in Hoffstadt. But Lacher also introduces elsewhere another measure of projection, namely half the depth of the window jamb, which he again fixes at 1/3 the thickness of the wall, thus being f g in Fig. 841. He then also gives the same distance to the projection of the plinth, but it is to be noted in this that these dimensions assume the theckness of the wall to be 1/10 the clear width of the choir. According to this rule the cornice would project about 1/5 or 1/6 of the thickness of the wall. These projections are frequently confirmed on the works of the 14 th and 1_ th centuries. But on the Early Gothic works the roof cornice as a rule has a greater projection, and especially if it forms a gutter for water.

Generally it is first the structural function of the cornice that determines its projection en every single case, and the thickness of the wall that sets a maximum for it by the possibility of execution.

But further we might for the simple cornices only fulfilling the function of carrying off the drip, as assumed in Fig. 840, also make the projection dependent on the distance between two cornices over each other, so that the roof cornice, whose distance from the window sill cap is greater than from that to the ground, and thus has to protect a greater height of the wall must also have a greater projection. In reality this wider projection on the later works is found in the projecting edge of the roof, but on the older was already made by the form of the cornice. Therefore we might sooner give the preference to the

to the arrangement of a more projecting roof cornice, than of its lesser projection on the later works that must be referred to a certain timid ty for a definitely expressed horizontal termination, which characterized the later style, but is entirely foreign to that of the 13 th century. It is further possible that the peculiar crowning of the windowsgable rising above the roof,cornice on the richer works from the 14 th centuryonward allowed the horizontal termination to appear as a possible denial of a characteristic of poverty.

Therefore if the before mentioned determinations of the measure of the projection at first also seem suited for the window sill cap, then is found the equality of this projection with that of the plinth is just as little retained accurately on the older works, as it is founded in the nature of the thing. Accordingly these rules at most have only the use of affording certain starting points for avoiding exaggerations and disproportions, and another will also not claim the very words of master Lacher, for he says himself, "but it is not thereby stated, that you must follow him in all things, than what seems better to you, that it may be better according to your good idea; it is useful to everyone when he can, and knows how to employ something."

Plinth.

The base in the beginning with a preference for the Attic base was correspondingly divided, or was even composed of rounds and hollows, that on account of a good removal of water was simplified or condensed. Also already early appeared occasionally on the exterior a simple wash, that gradually became more common and finally lent to the cap of the plinth even the name of wash moulding.

The height of the plinth from the ground outside is found to be determined by the measure of the thickness of the wall in n nearly all preserved rules of the masters, and then by Lacher this determination is extended, so that the plinth should follow the irregularities of the ground by steps. Such an arrangement is foreign to modern architecture in a special degree. Therefore we show in Fig. 842 the arrangement of the plinth of the church at Frankenberg. A greaterrheight of the wash moulding is then found, especially where it is divided in two or more parts.

The plinth occurs either alone on the exterior or also in the interior as assumed in the right half of Fig. 840. But since as

a rule the internal height from the floor is higher than the external, so that steps are arranged before the portals, then the height of the plinth either becomes less in the interior than on the exterior, or the internal cap must lie higher than the external one.

Instead of the internal plinth is found in most French works, as in the minsters of Freiburg and Strasburg, both a step seat, (thus in the left half of Fig. 840), whose upper edge is enclosed by a chamfer or a stumpy moulding, and on which is set the bases of the rounds as on a common plinth. When the surfaces of the wall wnder the windows are then animated by blind arches, as in Figs. 844 and 855, then the bases of the shafts of the l latter may stand on the second step rising above the first, as well as generally with the greater projection of the rounds, t the width of the lower step may be divided into two or more divisions. By the unequal heights of the different plinths of the rounds thus received can result especially picturesque combinations. The height of the steps is the usual height of a seat, if they are generally to serve as seats.

External window sill cap.

The window sill cap always has an importance subordinate to the roof cornice, and therefore mostly consists of a simple moulding made in the height of an ashlar, yet there are also found richer forms in which under the drip is formed either a simple cove or one filled by leaves (Fig. 855).

The height of the window sill or rather that of the cap forming the lower part of it is determined by Lacher, so that it shall lie above the wash andistance equal to that between two buttresses. This proportion is perfectly suitable for certain average dimensions, but would be too small for the lesser and wouldllead to considerable heights for greater, and besides by each greater distance of the flying buttresses apart, as then are found in the nave or even in the parallel extension of the choir opposite the polygon, would be entirely illusory and are found disproved in mediaeval works by the most decided variations. Thus the height in kuestion on the chapel of S. Boniface at Fritzlar amounts to 1 3/4 times the distance between the flying buttresses, but on the choir chapels at S. Ouen have scarcely half this width.

surface of the wall and around the buttress. Sometimes is found such an extension on the sides of the buttress, for a far better reason that a lower position of the sill moulding, in the reverse direction below certain windows, whose sills are thereby mowed higher to afford the height required for a side doorway under them.

Internal sill moulding.

In the interior the sill moudding has no wash but a groove to receive the water running down on the window, and therefore takes the form like that given at c, and may occur in varied relations with the rounds, when it extends around them (d in Fig. 840) or stops against (e in Fig. 840), or passes under them so that then rest on it. Extension around can be in the same form, or it may be a ring placed at the height of the sill moulding with a different shape (c in Fig. 840). The round can be set directly on the sill moulding if the projection of the latter is sufficient, or so that the projection of the sill course is aided by a corbelling connected with it (as at f).

As an intermediate between both arrangements might be that, whereby beneath the sill mouldingstand single rounds, and on a capital in the height of the sill course stands a triple one corresponding to the vaulting rips. Such an arrangement could result from Fig. 840, if the corbel were replaced by a capital and a round.

Further is sometimes found all three rounds connected together, the two smaller are on the sill course, while that is either b broken around the middle larger one or stops against it.

All such arrangements aid in strengthening the wall beneath the sill course, and the latter may even replace the sill moulding in the form of a simple wash, as in the choir of the church at Wetter (Fig. 843), as then is the latter generally also lacking in the interior of simple works.

We also note, that the difference between the breaking around on the stopping of the various mouldings against the rounds is characteristic of the various periods of Gothic art, in so far as in the older works the rounds formed on the ends of the ashlars are connected with the body of the pier by these mouldings broken around them.

Treatment of the lower part of the wall.

The wall beneath the window has the purpose of enclosing the

The height of the window sill course will consequently be so determined, that in all ordinary cases is attained a height above the floor exceeding the height of the human body. For actually it is still the latter which fixes the distance in question, so that church windows shall exclude the possibility of looking out, opposed to every idea in secular works; thus the underside of the window sill moulding must lie at least the height of a man above the ground. (Our Fig. 840 has the height fixed at 1 1/2 times the height of a man, that we express by a b in the proportion to the whole, and then the window sill is placed about the thickness of the wall above this lower edge, so that then results the inclination of the wash). An increase of this height may be required by certain arrangements occurring in the interior, such as choir stalls, sedilias, by entrances to be arranged under the windows, and further by the magnitude of the entire work, to which is to be denied as little the necessity of a certain indeterminate proportion of the details, since the magnitude of the latter can alone be developed therefrom.

Generally a triple scale will be made the basis of every rationally executed building, particularly that of the proportion of the whole, that of the duration and of the size of the materials, thus the average height of the courses to be used (so t that one may assume three squares connected together and thereby find the separate dimensions from the resulting differences.

On many simpler works is wanting the moulding accompanying the lower edge of the sill course and thereby all horizontal division between the wash af the plinth and the roof cornice. Such is not directly required by the nature of the thing. But since the addition of the wash of an undercut moulding aids the removal of water, an extension of the latter may be required in the width between two buttresses fully occupied by a window and the breaking around the buttresses of the first projection added here. In any case the effect of this horizontal division is favorable by the contrast with the higher proportion of the mullion of the window, and therefore this arrangement is to be preferred to that occurring on certain later works like S. Blasien in Münden, according to which the sill course returns vertically at each side of the windou to a height of about half the width of the window, and then continues horixontally on the

room externally and op supporting the window jambs. In a static sense it can further serve to stiffen the adjacent buttresses against each other (Fig. 837), to assist the strongly stressed lower portion of the buttresses, to transfer the pressure to a greater ground area, and by a longitudinal connection of the lower masonry of the buttresses reducing the danger of different settlements in unequal soils. According to the conditions there predominates ona or another of these duties.

In the wall has no buttresses or only small ones, then naturally the greatest stress falls on the lower part of the wall, it receives a comparatively great thickness, which is uniformly continued without deduction and small breadth of the window. But on the contrary for wide windows the buttresses are properly the supporting bodies, and this is reduced the importance of the lower wall, and as previously mentioned above (p. 337), and it t then generally has less importance than the wall arch and therefore can be made thinner than that, or where this will not do, may at least be reduced by recesses in volume.

Recesses on the external surface of the wall are rare, but on the contrary those inside are the more common.

Arcades beneath the windows.

First may the internal strengthening od the part of the wall under the windows, on which the rounds of the wall arches usually stand as in the side choir of Notre Dame of Dijon (Fig. 844), is supported by two little columns adjoining the little columns connected by arches, so that a blind arch results beneath the sill moulding. For a greater width must the number of these blind arches and of columns supporting the arches be increased, and there results those arcades according to the French expression, which in their richer form are in combination of the upper window in the clearstory with the triforium, at least in formal effect are allied to the windows of the side aisles.

In the greater number of the French cathedrals, but in Germany in the minsters of Strasburg, Freiberk etc., is found this mode of treatment, that removes the last remnant of the plain wall surface, and so essentially contributes to the overpowering richness of the whole. Their nearness of these blind arches to the eye permits a richness, a refinement of details, for which was scarcely found opportunity at any other place. Distinguished

in this respect are the arcades of the S. Chapelle in Paris and of Strasburg minster; the latter with a very simple arrangement, so that the capitals passing into the square and terminating c columns connected by strongly profiled pointed arches with inserted trefoils as in Fig. 855, and the spandrels produced between the arches are divided in four panels by inserted circles, the middle one of these bearing a representation of a figure, while the three smaller triangular spandrels are adorned with rich foliage. The effect is even enhanced by the arrangement of the corbelling connected with the plan of a gallery, decorated by foliage and placed at the height of the capitals on the wall behind (Fig. 855), by which the columns come to stand entirely free. For further concerning this peculiar form, see Galleries, p. 354.

In contrast to the usual arrangement of equal columns and arches, there alternate in S. Chapelle larger and smaller columns, so that the former being connected by pointed arches form two panelsunder each window, that are again divided by the smaller columns connected with the larger by trefoil arches. As a rule the bases of the little columns stand on a continuous step as in Fig. 845, more rarely directly on the floor as in the cathedral of Chalons sur Marne.

The arches themselves are formed according to all possible lines, as round arches in Fig. 844, as pointed arches, either plain or with cusps as in the cathedral of Meaux, as round trefoil arches as in the cathedral of Amiens, as as pointed trefoil arches in the minsters of Strasburg and Freiberg. In certain German works of the transition style are then found the arrangement also retained sometimes in the Early Gothic, whereby in two recesses beside each other the little middle columns are replaced by corbels. Such an arrangement from the collegiate church of Wetzlar is shown in Fig. 854.

A deviation from the regular placing of the columns produces a variation, if an entrance is placed in the wall concerned, whose width then equals about two of the recesses. Thereby is then modified the form of the arch, and in the simplest cases it is replaced by the straight lintel. Such an arrangement is found in the minster of Freiburg (Fig. 845).

Since the columns of these recesses stand in the plane of the

side arches, then is omitted the need of number and of placing them in direct connection with the window jambs, and such results only for the middle mullions of four divisions in the way that such stand either over the middle column or the m middle of the arch of the recess, but the other columns are sidewise from the window jambs (Fig. 845 a, where the columns are designated by a and the window jambs by b). On the contrary on later works the endeavor for this relation leads to placing the little columns of the arcade beneath the window jambs, thus to set back a portion, so that the rounds of the side arches pass down before them to the ground, and the backs of the recesses come to be in the plane of the glass. However there can still be effected by the sill moulding intersecting the rounds of the side arches a separation of the window from the blind niches as in the cathedral of Meaux and in Chalons. But this entirely disappears if the sill moulding intersects the window jambs, and the latter exteods to the ground replacing the rounds of the b blind arches, as in the transepts of the cathedral of Meaux.

Blind arches without windows above them.

Sometimes these blind arches are also found without connection with windows above them, as in the vestibule of Freiburg minster. In this case the sill moulding naturally vanishes over them, since the horizontal termination loses its importance, but then the gable is best suited to the nature of the pointed arch for covering it, by which its apex is loaded and its upward force is restricted. Likewise the stability of the columns will be increased thereby, which in Freiburg occurs from placing a figure, and we thereby pass in this ornamental form here to the expression of a ground principle of Gothic architecture.

Blind arches with narrow windows.

When the window does not entirely occupy the space between the buttresses, then blind arches extending the full width at both sides of the window, plane wall surfaces produce a heavy effect. (Indeed in Freiburg this arrangement is found connected with the plan of a choir aisle, to which we shall return later). To avoid this evil result the blend arches may also be repeated above the sill moulding on the wall sufface, or may be omitted below it, and only for the width of the window and either in the thickness of the jamb or within the depth of the member extended to the

ground is found in certain later works also without blind arches, indeed in the interior as well as on the exterior, so that in the last case the inner surface of the wall remains plain.

A particularly rich example of the last kind is found in the choir of the church at Freiburg-on-Unstrut, dating from the 15 th century, where directly beneath the sill moulding on whose wash stop the jamb members, it is enclosed by the same arrangement having the same width as the window, and for-sided recesses occur having panels decorated by reliefs, while the outside members of the jambs directly below the sill moulding form a series of suspended bound arches with cusps, that in a manner form a canopy over the reliefs.

Simple blind arches.

As a substitute for all such richer forms are then usually found on these walls simple blind pointed arches lacking all direct connection with the windows, as in the choir aisle of S. Gudule in Brussels and the transepts of the church in Wetter, and farther in many N. German brick churches.

Arrangement of windows.

Height of the window.

For the height of the window arch is determined a maximum, so that for its body may remain beneath the side arch. This condition results of itself, if the window entirely occupies the space between the buttresses, and hence the window and side arches are either concentric or coincide, as assumed for the middle w window in Fig. 840.

With a smaller width of the window, the concentric arrangement of windows and side arches will then only remain possible if the proportion of the width is such, that no extremely pointed form is compulsory, but is necessary in no case.

A minimum height of the window is determined by the common ground lines between window and side arches. Thus the heights of the side windows are determined in Fig. 840.

On the ratio of the height of the window to the height of the wall beneath the sill moulding it can only be established, that the former shall predominate, as based on the nature of the matter.

Maximum width of window.

It has already been shown how the greatest width of the window results, so that its jambs lie directly at the buttresses so t that their sides form the jambs, from which start the arches.

Now since for oblong bays the ground lines of the stilted window arches come to lie at a certain height, to which the cross arches are pushed up in a notable way, then the window arches or a strengthening thereof is furnished by the proper side arches, here extend exactly like vertical surfaces forming the edge of the compartment. The prespective view (Fig. 846) shows this arrangement at b, that is found especially bold in the hexapartite vaults of the choir of the cathedral of Beauvais, whose arrangement is shown in Fig. 847. Here the side arch is cut away at one side by the vertical lines bordering the halfway rib, while at the other side the line of intersection is visible behind the cross rib omitted in our Fig. Accordingly the outer rib of the pointed arch on which rests the compartment no longer forms a complete pointed arch, but only a segment, so that the compartments intersect those surfaces at a very obtuse angle.

This otherwise scarcely visible peculiarity is found in the choir of the cathedral of Toul, whose arrangement is shown iu the elevation and plan in Figs. 850, 850 a, executed for the p purpose. As shown by the plan, the buttresses of the choir ending in the half demagon are moved so far inside, that above the window sill an opening extends through them, and before their tops project the shafts bearing the cross ribs a, while the anges b and this pier subdivided by the inserted shaft receive the side arch continued over this passage as a tunnel vault. On these internal buttresses lie the jambs of of the window, that are turned as pointed arches as shown by the elevation, but thereby the external line of the before mentioned strengthening arch and f further the tunnel vaults between the piers are required by that broken line of the pointed arch, whose starting therefore lies high above the capitals of the rounds c found in the ground line of the cross arches of the choir in Fig. 850. But since the span of the cross ribs in the middle square preceding the choir is far greater than in the polygonal choir, there results for the former a far greater height with equal height of the crown and a similar form of arch, and thereby the height of the capitals in the transverse aisle as well as on the pier of the choir is placed so much lower, and on which rest the cross ribs resisting the entire thrust of the ribs of the polygon.

At the latter height terminate all choir piers in capitals, on which rest the pieces forming that difference like independent piers.

Side and window arches.

If the windows extend from pier to pier, the form of window arch is determined by the concentric line of the side arch. But where the entire construction causes, that the crown of the arch lies very near the horizontal top of the wall, particularly with equal heights of all the crowns of the vault, with a pointed form of window arch and even for these equilateral, the upward force of the arch does not appear alone to break this horizontal limiting line, but in many cases actually produces this effect. Hence in this case it is better to place the crown a little lower, and to construct the arch with a smaller rise (giving it the form of arch with centres given by dividing the base in 4 parts). Fig. 849 will give the section in Fig. 849 for the eastern side, only with the assumption of a pointed form drawn instead of Fig. 849 a. On works executed with greater richness are then found for loading the apex of the arch the crowning of the window arch by a gable, first occurring on the S. Chapelle in Paris. Further see former p. 342).

Further the pointed form of the side arch, that also requires for it again a pointed arch (even though excentric), or by the arrangement of several windows beside each other in the side of the same bay, at least a grouping to rise toward the middle. Such is obtained by the arrangement of two windows, as found in the Regensburg cathedral and the church of S. Peter at Lübeck, by the addition of a round window betwiin the two window arches and the side arch, by the plan of 3 windows beside each other, as found on Early English and certain German works, with a greater height of the middle window.

Conversely in many French works, as in the transepts at Amiens, the arrangement of a wheel window for the entire width refers to the semicircular form of the side arch.

Independence of side and window arches.

The necessity but not the validity of the pointed arch or of the culminating form of the window vanishes with tha vault itself, and likewise with the assumption of that rib vault represented in Fig. 96, in which the compartments are replaced by stone slabs. Therefore are found in the interior of the Freiburg tower, from which the construction is taken, between each two such ribs are three pointed arched windows beside each other.

The same mode of construction found a somewhat changed appli-

application in the older churches of Burgundy (Fig. 848). Particularly here the window wall between the buttresses is moved out so far, that within it passages lead through the latter. The side arches of the vault then became free of the wall lying there on as freely projecting arches like the other ribs, and over the junction of the compartment are leveled by a wall built on them and connected with the window wall by utone slabs laid thereon, which accordingly form a horizontal ceiling on t the width of the passage, and their upper surface either forms the channel for water or receives it; Fig. 848 shows this arrangement for Notre Dame at Dijon. There a is the side arch, b the internal buttress with the passage, c the stone slab laid above, d the window wall, that is opended by 3 pointed windows of equal height. Likewise a rectangular form of window would be suitable here, with a covering of sufficient strength to support these slabs. In Viollet-le-Duc is found an example taken from S. Germain des Pres, where in the rectangular windou is inserted a great pointed arch divided into 4 panels by large and small mullions, and the spandrels formed between the latter and the rectangular enclosure are again filled by inserted trefoils, the latter sufficiently strengthening the horizontal covering.

A particularly ingenious and splendid application of the same construction is found on the rose window of the Strasburg minster. The passage here lies outside; the window proper recedes to the place of the side arch in Fig. 848, while the window wall in the same Fig. is replaced by a circle with suspended arch inside, turned between the buttresses, floor and the ceiling of the passage, and the spandrel between the latter and the sides of the square is filled by open and beautifully treated tracery. Now conceive in the example represented above, that the window wall as in Fig. 848 is set in the outer side of the passage, t then would the spandrels be perforated in the same way and glazed, and thus the enclosure of the circle by the square would appear gust as organic, as that by the pointed arch according to the usual form of vault.

Jambs and mullions.

As previously stated, the mullions in works of the 12 th century assume a greater, and consequently the jambs a lesser importance. We exhibit it on the plan of the window of the choir in Wetter given in Fig. 851, where the thickness of the mullion

amounts to about half of the wall, and the jambs consist of simple splays. . The latter form is that most frequently occurring in the simpler works, while richer jambs are formed by rounds placed in the right angle formed in the projection of the wall. Then either the capitals of these rounds receive the members of the arch in another ground form inscribed in the right angle of the ashlars, or the shaft continues in the arch as a round. The members of the form commenced by these little columns then continue on the mullions, and thus become more complicated in the arrangement of large and small mullions. Only in Strasburg the difference between the mullions vanishes, since the larger only consist of two smaller ones placed beside each other (Fig. 855 a at b).

The thickness of the window jambs and mullions is determined by Lacher at 1/3 the thickness of the wall for each. In other places in the same manuscript appears to be given for mullions 4/10 the thickness of the wall, as also assumed by Hoffstadt, the thickness of the jambs then being 3/10. Both sizes correspond to most German works of the 14 th and 15 th centuries, where the desire for rich combinations of tracery and too slender forms of mullions led to the small size of the latter. An example of this kind is shown by the square in Fig. 841.

Even in cases where the window occupies the entire width of the bay, are sometimes found such rich members on the arches entirely or partly intersecting the sides of the buttresses. Such an example from the choir of S. Ouen in Rouen is shown by Fig. 841 b.

Sometimes as on the upper windows of the church at Haina, (Fig. 851 a) the mullions connected with the little columns lie nearly in both faces of the wall, and are separated therefrom only by a cove, so that they occupy the full thickness of the wall. Then the window arch is enlarged externally by a projecting drip moulding of concentric form, which in the ground line of the window arch is returned horizontally and continues a short distance, then goes vertically downward and again horizontally around the the buttress, forming the border by its offset.

Hood mouldinm.

Moreover there occur here members enclosing the arches and projecting from the face of the wall, that generally occur on the works of the 13 th century, a very effective means for increasing

the importance of the arch and animating the surface of the wall.

As a rule these hood arches take the members of a simple drip moulding, yet on French works are usually cavettos containing rosettes or foliage.

While they form the window arches in Haina, they are certainly found in other places as protections of these,so they are separated from the members of the jamb by a plain band.

Instead of the rectangular return, which is assumed there and that results from the proportion of the height of the beginning of the arch to that of the ground line of the window arch, they usually continue horizontally in the latter and stop against the buttresses, or they rest on corbels beside the window jambs at the same height.

Passages.

For the maintenance of the different parts of every building and the reparaaion of injuries occurring, easy accessability is of the highest importance. But more than elsewhere will this be necessary at the windows, and on Gothic churches of the earlier system it is provided by the arrangement of passages at the height of the window sills, and that can be constructed in the most varied ways.

Structural principles of the passages.

The modern custom would be, assuming otherwise the adoption of the system of Gothic construction, that lying nearest and s shown in section in Fig. 852, according to which the passage c consisting of a continuous balcony supported by corbels, that leads outside the vaulting shafts standing at the face of the wall. In Gothic art is found in its right endeavor to obtain the greatest effect with the least means. It then sometimes utilizes the projection created for the passage to reduce the span of the vault, accordingly a lesser height and measure of resistance sufficing for the entire construction. It employs detached columns, that stand in the outer face of the passage, and connects these with the wall or rather with the buttresses by a strong lintel, whose end a forms the springing of the rib, and which is supported by corbels from the face of the wall, but turns a tunnel vault over the width of the passage, which at the same time also forms the side arch for the middle vault, and s supports the columns either by strengthened corbels or by a pier extended from the ground. With the adoption of the latter cons-

reduction is only required a very small increase in the depth of the buttress, since as already stated, its depth acts in about the square proportion.

Hereby is explained the width of that internal pier in Haina, that by the mass pertaining to an earlier design, and not by the strengthened lower wall strength by buttresses, they were prevented from lengthening the upper buttress, a means that certainly could not occur in Freiburg. Further on the stability of passages, se later p. 358.

Passage in Strasburg minster.

In the most perfect form appears the arrangement of internal passages at the windows of the side aisles of the Strasburg minster (Figs. 855, 855 a). As shown by the plan, the internal detached pier is entirely enclosed by the three rounds of the cross and diagonal ribs extended from the floor and the two at a standing on the floor of the passage, which support the free side arch.

The width of the passage is not as in Fig. 853 covered by a simple tunnel vault, whose richness is increased by that of the compartment d, but extends over the latter by an extension concentric with the side arch, that is received by the arch b extending lengthwise on the face of the wall. Since further the i interior opened buttress covered by the rounds, required for thrusts of the vaults of the side aisles, aside from the buttress system of the middle aisle, to have strong external buttresses, rather than to strengthen the latter, thus their width was reduced ao the least dimensions, and its face f recedes far behind that of the rounds of the side arches. Thus the entire arrangement of the boldness of the covering of the passages shown in Fig. 848 by horizontal stone slabs is nearest, and the advantage is peculiar to it over the latter, that it avoids the unquiet effect, produced by the latter by the onesided abutment of the compartment against the wall set on the side arches as at x.

In Strasburg the floor slabs of the passage are supported by the blind arches mentioned above (q in Fig. 855). Since further the window jambs do not directly adjoin the buttresses, then must the jambs be carried down at least to the sill moulding, and thereby as well as by the plan of the passage occurred an unnecessary breadth at the height of the sill moulding. Hence the thickness of the wall is not alone reduced by the corbellign

construction we reach the system of the internal buttresses furnished with passages at the height of the window sill. Below the passage the piers in the simplest cases are again connected by arches of tunnel vaults, on which lies the floor of the passage, while the rounds either extend up from the ground or are corbelled out from the face of the pier at the height of the passage. (Fig. 853). The last arrrangement is found in the choir and transepts of the church at Haina, and is entirely in place, since the corbel bonded to the pier by the great and concentrated weight of it affords a sufficiently secure position.

Stability.

In Haina (Fig. 833 a) and in the side aisles of the Freiburg minster the piers before the passage are thin but very wide. The adoption of such great breadth of the pier is attributed to the view, to offset the weakening caused by breaking. Yet this weakening exists an a far less degree than it appears.

If we provisionally assume hhe pier in Fig. 853 to be solid, then with insuffieient strength of it are possible two results. the first would be a bending of the wall outward, and then occurs if the resistance opposed to the thrust of the vault by the overlying courses by friction, assisted by the adhesion of the mortar is insufficient because of the size of this area or by too small loading. The second effect would be an overturning of the pier about the foot of the front face.

The first effects of these by bulging outward is only to be cared for in regard to the thrust of the vault by directly applied courses, that according to the course of the line of pressure lies at 1/5 to 1/3 the rise above the springing of the vault. Hence it follows that a fracture of the pier or rather of the springing of the arch at the so determined height or above is certainly impossible, but below this a bulging of the wall cannot occur. We here add the example given in Fig.854 from the S. transept of the collegiate church at Wetzlar, where above the capital of the pier is found the fracture extending through the springing of the arch, that scarcely reaches the limits of possibility.

But the result of overturning the pier can be aided by the f fracture of the pier only so far as the feared pivot is moved back from the foot in Fig. 853 toward the point c, whereby the weight of the overturning mass is reduced by the volume of the fracture and of the standing internal pier. To equal this reduc-

already mentioned above, but also by the bold membering of the sill moulding, and yet more because the depth of the jamb still projects beyond the extreme line of that moulding, so that the bases of the columns project beyond its edge by a horizontal bottom surface h.

As a rule the passages lack railings, but at the same time the window wall affords entire safety. Only in Freiburg was the outer edge furnished later with a gallery of perforated Late Gothic tracery, which is then wrought in relief on the fronh surfaces. of those internal buttresses to the rounds, but being loaded here by the upper mass of the wall, it produces no pleasing effect. Besides the gallery conceals the lower part of the window, and would be better if replaced by iron rods reaching between the piers and with ends let into them.

External passages.

We have so far only mentioned internal passages, but they can also be arranged externally in the same manner, there leading through the buttresses as on the side aisles of the collegiate church of Wetxlar, on its choir polygon and on the church of S. Elisabeth at Marburg. However it would be nearest to place it against that side of the window occupied by the glass.

Since very generally in the arrangement of two rows of windows over each other, the lower was glazed from the inside anf the upper from the outside, also accordingly the position of the p passage differs. Those two passages are found on the church at Wetzlar, the lower being inside and the upper outside the window. (Figs. 856to856 c). The entire design bears a very primitive stamp, so far as both passages as shown by the section in Fig. 856 a, lie obliquely beside each other and thus require a width, that is indeed afforded there by the unusual thickness of the wall and priers. Thus the utility is further lessened, to be derived from a continuous corbelling or by arches turned between the piers for the arrangement of the passages, and therefore recourse is had to a series of unusual expedients.

We first call attention to this, that the faces of the rear walls of both passages a and b lie over each other (Fig. 856 a). Accordingly all projections from the window mullions must be omitted externally to avoid a reduction of the width of the passage, but the glass itself is set so much inside the face b, that on the middle mullion was yet possible the arrangement of the

outer calking fillet was possible. The middle mullion is then expressed externally by no moulding that receives its full depth inside, by which it extends down on the face a, and rests on a corbel at d about 8 m above the lower passage; but since it likewise projects inward from the face b of the wall, it must stop on the sill of the window forming an internally projecting moulding g.

The lower passage leads through both these walls. Before the upper passage lie externally the piers f without capitals in F Figs. 856 a and c, from which stone beams ornamented by leaves extend to the wall, that serve as bases for the three tunnel vaults turned over the external passage between each two buttresses. By the arrangement of these piers and vaults is at the same time removed the otherwise unavoidable effect of all external members on the window mullions in a very happy manner.

This arrangement transferred from the Early Christian and Romanesque periods, of detached piers or columns as supports of certain tunnel vaults (dwarf galleries, etc.) is however peculiar to the passages of the transition style, indeed being often turned toward the interior and connected with the windous, so far as that a window is found beneath each tunnel vault. In Still Romanesque treatment it is seen in the middle aisle of the minster at Bonn, where the windows are only placed at the height of the side arch, and therefore beside this arcade remains the surface of the wall, behind which the passage extends and opens to the interior beside the windows.

A nearly allied but far more complicated design of double passages over and yet beside each other as in Wetzlar is found in the cathedral at Besancon, where the window utory is connected with the arrangement of the triforium, and to which we shall r return later.

Preferable in this respect to this arrangement beside each other are the passages placed at different heights vertically over each other. Such a design originates in the simplest way when both passages are placed at the same side of the window wall. Such an example is found in the S. transept of the church at Wetzlar as shown in Fig. 854, so that the floor of the upper passage only temporarily in case of need connected the openings in the springings of the vaults by means of beams laid across, that could be removed afterwards. At the least we might find in

the reason for the arrangement of these openings.

A permanent and actually built arrangement of double passages fully requires that of a double row of windows, such as found on S. Elisabeth at Marburg, where the passages lie on corbellings extending from one buttress to another. In the same manner can they also be supported by arches turned between the buttresses. These can either be continued as tunnel vaults for the width of the passages, or be free for a certain distance and bear slabs laid to the wall as in Fig. 848.

External and internal passages are connected.

In this arrangement also lies sometimes the simplest solution of the problem of placing the passages at opposite sides of the window wall, namely that these arches alternate in place with the lower windows, and hence the upper windows come to stand over the arches. Thereby the upper passage lies outside and the lower one is inside, the floor of the latter being either borne by cross arches as in Strasburg, by blind arches or lastly by corbels, niched by continuous corbelling as in Marburg, or by separate corbels connected by arches as in the churches at Gelnhausen and at Wetzlar. The form of the upper window can harmonize with that of the lower as on the church of S. Elisabeth at Marburg, or may differ from it.

Likewise here the system of construction of the passage, that just in the same manner as we have already stated concerning t the side aisle on p. 351, first determines the choice of a pointed or horixontally covered window form. Generally for small heights a diversity in the two rows of windows is more tasteful, rather in the way that the lower division consists of two or t three windowu of equal height, the upper being composed of one divided by mullions and covered by a pointed arch

Doubled row of windows.

In all cases with a great development in height the Early Gothic arrangement of a double row of windows is to be preferred to the extremely slender treatment of the window in the later period, since besides the more tasteful effect it affords better access to the windows and a more favorable longitudinal stiffening (p. 338). Indeed men had become accustomed to regard the slender windows as a necessary product of Gothic verticalism, indeed as the only expression of ecclesiastical charcater in t the measure, that it is accepted in even church buildings in

Conversely the design of the church of Marburg is certainly from Romanesque reminiscences anf those of the french single-aisled choir and transepts, to which we have already had to refer as well as to the choir of Regensburg calthedral, only thereby an entire unity of effect of parts in several aisles, or to approach the magnificence of the arrangement of a choir with aisles, or finally to make possible a more perfect circulation, led to retaining the subdivision of the height of the nave.

To this it would be opposed, that the last could pe expressed by the arrangement of stairs, that moreover the division in height of the choir and transepts does not always harmonize with that od the aisles. Here we shall only refer to the cathedral of Noyon in which in the middle aisle above the side aisle and thus directly above the side arches is a vaulted gallery, over which is the triforium and above the last is found the clearstory windows, while in the transepts the division in height is changed, so that over the height of the dividing arches and t thus at the height of the floor of that gallery is the triforium, over the latter being a double row of windows placed over each other, so that before the lower and inner passage is found and before the latter is an outer one.

But the intention is further to establish a unity between the different parts of the same work required by no internal reasons, just as far from the nature of Gothic art as the other, to simmulate an effect corresponding to an entirely different conception.

It must be further noted here, that when verticalism reaches an enhanced expression of Gothic construction, this nowise suppresses horizontalism, and that on the contrary the endeavor to elevate the former principle at the cost of the latter so as to predominate alone, even form the weakness of the later works, which by the opponents of this art is erroneously represented as a necessity thereof.

If we now pass to the Late Gothic arrangement of windows occupying the entire height above the sill moulding, which height is often to increased, that the proportion to the width is scarcely intelligible, then must we make prominent the defect, that this defect is so exclusive and injurious to all other parts to be pleasing, and therefore has already produced many ugly arrangements. It is further unfavorable to the effect of the glass, both for the adoption of a white or colored pattern from the

necessity of innumerable repetitions, as well as with the representations of figures, and in the later peroids of Gothic art it led to those painted canopies like towers over the figures, that strictly taken can only be regarded as filling spaces.

But further that excessive height of windows also creates a need for their accessability by passages. In the recognized requirement of the latter is to be sought the proper structural ground for the Early Gothic design of a double row of windows, whose effect then is an art form as shown by the existing examples, at least as not inferior to the later arrangement. It is in the nature of the matter, that this design in general like every one, is connected with a certain relation of magnitudes, and requires a careful gradation of heights to widths. The minimum dimensions that permit a double row of windows must lie within a width of nave of 8 to 9 m, where the height amounts to about twice the width.

For this proportion we try in Figs 857 to 857 c the design for a bay. We make there the length of the bay, a b in Fig. 857 c, equal to h f the width, the entire width of the pier a c equal to 1/4 the diagonal with regard to the openings, and then assume a sufficient thickness of the pier and a corresponding location of the outer face of the lower wall through the point e. Then in the internal elevation of Fig. 857 the height f f′ = 4 a b and accordingly the rectangle a b a′b′ is determined as well as its diagonal and the lines a f′ and b f′, and further the line a i is drawn as diagonal of the square, so that the different intersections of these lines indicate the heights k, l, m, n and o.

Likewise in the external elevation of Fig. 857 b the height a b is determined by the width between two buttresses, the height c d by the diagonal of the square described with this width, the height c g by the diagonal of its cube, but the height e f by the sum of the widths a b and c d. The cross section of Fig. 857 a then shows the construction of the whole, in which over the lower windows are turned two of the tunnel vaults supported by a middle column, and the arch of the upper window inside is strengthened by the side arch, outside by the arch turned between the buttresses.

The predominance of the upper windows over the lower is first required by the necessity, that the opening through the buttresses lies below tte point of application of the thrust of the vault.

Therefore at most an equality of both divisions is to be obtained, but not the reversed proportion.

When we have explained here the arrangement of a double row of windows first in relation to single-aisled churches, what is said is likewise true for the side aisles of three-aisled churches, but the entire arrangement finds renewed application in connection with the design of double side aisles over each other, to which we shall return later.

Effect of openings on stability.

An abutment with great openings always produces the impression of great boldness, in some cases even a certain insecurity. In famt may be conceivable openings at unsuitable places, and on the other hand if rightly employed may lead to surprising boldness, such ar are shown by the old works and proved by an examination of the stability.

Permissibility of the opening.

In an abutment mass, that must resist side forces, only occasionally comes the question of strength of materials, while the greater part of the materials usually serves only as a heavy mass to increase the stability. It is evident that first openings may be made in these more weighty parts, so far as they do not cause an unfavorable arrangement or too great reduction of weight; with correct use they may even serve for a better distribution of the weight or a saving of unnecessary masses.

In some circumstances are possible openings even in the more strongly stressed parts, they can comple there a desirable location of the pressure, and sometimes also remove the statical uncertainty concerning the assumed distribution of the pressure.

If it is desired to follow the entire course of the pressure from top to bottom of a perforacted abutment or a pier with an opening, then is sought in the ordinary line of support (p. 141), where the vlomue lost by the opening is also omitted in the calculation of the weights. If the line of support corsses an opening, there is nothing distributing in this. In such a place the resultang must be ädivided, so that a corresponding portion of the pressure is transmitted in the masonry at each side of the opening, whose magnitude and direction cayn be found (See below).

Since the safety of the structure must not be affected by the opening, two requirements are to be established, first that the danger of overturning is not increased, and then that the edge

pressure be nowhere too great, or besides the latter requirement, also that for preventing the opening of the joints, the resultant must remain within the kern of the cross section.

Fall by overturning.

Safety against overturning. An abutment of the form represented in Fig. 858 under the influence of a side force H is firts inclined to overturn about the lower angle A. But if a higher bed L above occur great recesses or openings, the dangerous angle may change upward to K, the rotation indeed occurring if the moment of stability Q × a becnmes less than the overturning molent H × c, where Q is the resultant of all weights existing in and on the abutment, a denoting its horiqontal distance from the pivot angle K. The overturning is illustrated by Fig. 858 a and causes a movement of the centre of gravity S (Fig. 858) in an arc struck from K to S_1, so that the entire volume Q is to be raised the distance h_1 or T S_1.

Fall by overturning the wall of the passage.

Besides overturning because of the existence of a recession, overturning occurs in the manner exhibited by Fig. 858 b. The larger part K C D R of the wall lying beside the opening (Fig. 858) is rolled or tipped until the angle D lies vertically over K; from thence the mass already overturns of itself. The centre of gravity s of the part K C D R then passes in an arc described from K to s_1, its weight G is thus raised a distance h_2, and all the masonry lying above C D is at the same time with the angle D is raised a considerable height h_1.

Denote the weight of the upper wall above C D by P and the w weight of the supporting wall K C D R by G, then for this position on edge is to be performed the work $P\ h_1 + G\ h_2$.

On the contrary the work in simply overturning (Fig. 858a) is:- $(P + G) \times h_1$.

According to whether the first or the second of these expressions is least, is more easily to be feared a tipping (Fig. 858 b) or an overturning (Fig. 858 a).

If the weight of the supporting block is relatively small in comparison to the upper wall, then can be produced a much simpler indication; draw about K the circular arcs S S_1 and D D_1 and measure the ordinates h and h_1. If h is smaller, tipping ((Fig. 858 a) will most readily occur; but if h_1 is smaller, the

rolling (Fig. 858 b) is to be feared. Thus the arrangement of an opening cannot be regarded as an unstable place in the entire structure, so long as the distance h_1 is greater than h. T This condition will frequently permit the opening to rise to half or more of the height of the wall, and on the other hand openings are less to be feared the lower they are and the wider the supporting block beside them.

Distribution of the pressure to the two walls.

Allowable stress; position of the pressure in kern. When the safety of the mass of the body against the danger of overturning is determined as in the preceding, there is assumed no limit of strength of the building materials; since such does not exist, there actually occurs a crushing of the dangerous angle before the commencement of the overturning. Therefore the greater requirement is to be established, that in no place and particularly at no angle may the pressure on the material exceed a limit judged to be allowable. Besides for most cases is also the requirement that the resultant pressure shall not leave the kern of t the cross section. Which of the two last requirements is most stringent depends in certain cases on accessory conditions. The question of distribution of pressure in general has before been so fully treated (p. 137 to 148), that it only remains here to consider the course of the force in the present entirely definite case of an opening in a wall.

There is first sought the magnitude and location of the resultant for the horizontal bed above the opening (Figs. 370 and 371 on p. 140), and then this is resolved into the components that continue in the masonry at both sides of the opening. The analysis is executed for four different cases in Figs. 859 I to IV.

Some special cases.

Fig. 859 I. The resultant R is vertical and the supporting w walls are rather thin. If R lies in the middle between the two walls, each would receive half the pressure. But since in the drawing R lies more to the left, then would the larger component fall there, and R would be distributed to the two walls, j just as a single load on a beam is resolved into the two pressures on the supports, the components being inversely proportional to their distances from R, and can be obtained graphically as follows. Assuming the points of application of the components at A and B at the middles of the supporing walls, the magnitude

of R is laid off as the length C F, and the lines C A and C B are drawn and with these and the diagonal C F is found the parallellogram C D F L. Now drawing a horizontal through C, the d distances G D and E J give the magnitudes of the components sought.

The assumption that the points of application of the components A and B lie in the middles of the walls, can only approximate correctness, since the different locations of R and the varying thickness of the supporting walls and that may produce dangers in these as well as in the construction chosen to cover them. To decide with approximate accuracy in special cases, as for the position of R near one side and greater thickness of one or the other of the supporting walls, one must realize that the resultant R does not act at a single point, but that it is merely a comprehensive expression for the forces widely distributed in the area, as pefore illustrated by the representations of stresses in Figs. 375 to 377 .s well as Figs. 383 to 385.

Fig. 859 II. The resultant R is oblique with equal thickness of the supporting walls. It can be assumed, that the components are parallel to R and that the points of pressure A and B are given, so that the resolution is assumed as in Fig. I. The component lying nearest R will again be greatest. Accordingly the components are composed with the weights of the walls G and G_1, project below as M and N, and can again be combined in a result- and R_1 if required.

Likewise here the location of the points of pressure A and B are not to be fixed with certainty. As in vaults (p. 47) if a favorable effect of the plastic mortar is counted on, it is assumed that with correct construction it will be endeavored to keep the components as nearly as possible in the middle of the supporting walls, so that the point A lies about as far to the right as m lies to the left of the same. If one proceeds in this assumption, he can regard the supporting wall as sufficiently strong, so long as it is possible to locate the component in it, that if the pressure is nowhere too great, or also that the pressure may everywhere remain in the kern.

The direction of the components parallel to the resultant also occurs in some circumstances, and cases may occur in which one component is quite or nearly vertical, while the other is so m much more inclined (Fig. 859 III), indeed by vaults with strong thrusts they may be directed outward between the supporting walls.

It is to be particularly assumed that walls of unequal thickness, that with the otherwise corresponding construction the component is steeper in the thinner and flatter than in the thicker wall.

Fig. 859 III. With an oblique direction of the resultant, there is a thicker supporting wall at the outside but merely a t thin one at the other, though a sufficiently strong support. O Only a vertical force can be assigned to the latter. To find t the components a vertical is drawn through B to intersect R at O. From O is drawn the line O A and by the parallelogram the force R in the direction O A is resolved into its components, with which are combined within the walls their weights G and G_1. If the force passes unfavorably in the left wall, the construction can be repeated by moving A.

The actual position of A naturally depends on circumstances, and it may be strongly influenced by the length of the support at the right, for the most unfavorable case occurs if the support is too long (Fig. 859 999 a). Then the upper load chiefly rests on the angle C, and the transfer to the oblique force is thus generally impossible. A condition of rest can occur again only by the breaking off of a piece of stone at C, or after the sliding of the upper mass to the left, whereby the supporting wall rotates so far that the inner angle D lies above and with the adjacent parts od the surface receives the pressure.

Fig. 859 IV. The locations of the support and supporting wall are exchanged, otherwise being as before. The resolution of the forces proceeds with the sole exception that the intersection O is moved downward. If the intersection lies too far, this may be helped in a different way from the former case. R is first resolved into vertical and horizontal forces V and H. V is resolved into its vertical components acting at A and B according to Fig. 859 I. The support lying at the left will receive no p part of H worth considering, and therefore H will be entirely supported at the point E as B J. B J and B E then combined give the force B E in the stronger wall at the right.

Changing the load.

Where the loads vary, as where the wind exerts an influence, there will vary the magnitude of the resulting pressure R, and likewise its direction varies, there must naturally exist a sufficient safety for this case of loading, and it suffices to investigate for the two limits of R.

Mode of construction.

Narrow passages are best covered by stone beams or slabs of strong and tough stone; where this cannot be used, by corbelling and also by vaulting in special cases. If metal ties are generally employed, they will be in place over and below the openings.

That a proper transmission of force may occur, as clearly results from the previously described examples, a very careful execution that includes oversight of all important conditions of transmission and pressure is required for just those points. Caution is particularly required if at one side of the passage are employed tall columns of a single piece, while the wall at the other side is built of separate courses in shrinking mortar. What injurious influence can be exerted by too long columns, aside from their too great loading, is illustrated by the little sketch in Fig. 859 III a. That such particularly bold construction in mediaeval works has chiefly lasted very well shows, that the old masters in the execution correctly supervised all important requirements.

Arrangement for removal of water, gutters and gargoyles.

Fall from edege of roof.

The simplest and most common removal of water in Germany is that the water simply drops from the projecting edge of the roof, and by its overhang is prevented from flowing down the wall surface. The efficiency if this protection increases with the projection of the roof made by wooden construction.

If the plan if an always limited projection of the roof permitted by a stone moulding without a gutter is imperfect, yet it may be required by limited means, and it either assumes the form shown in Fig. 860, where the edge of the roof is directly over the face of the moulding, or it is according to Fig. 861 a board nailed on the projecting ends of the joists, that forms above the moulding an oblique surface increasing the projection.

Yet a more exact investigation shows many works in their present condition lacking a gutter, yet such was originally intended and either has already disappeared in the erection of the roof or in consequence of later alterations. Generally appear on simple buildings, especially if secular, that also gutters of wood or metal formerly existed.

Metal gutters.

Where suitable stone was lacking, the gutters were made of

metal. Yet many modern designs though imperefte in many respects, have an advantage over a construction occurring in works on the lower Rhine, where the gutter is in a manner prepared for by a board fastened on the beam ends in the external face (Fig. 862). It consists of a wooden bottom in the given case and a low parapet formed by boarding a low parapet with connecting beams a. The latter is then slated externally beneath the lowest slates of the roof and bent over the top of that parapet. These gutters are improved if desired, that if leaky the water is so led away that it cannot wet the beams. Particularly favorable are the f freely placed gutters above a wash on separate projecting stone corbels, as executed on the most recent Gothic brick buildings.

Stone gutters.

Stone gutters are formed by a channel sunk in the top of the cornice slab, then if necessary with a slight fall of the bottom toward the discharge.

With regard to this channle, its depth must be reduced as much as possible to avoid weakening the stone, but on the contrary the width can be made as wide as possible. The sides may be formed by slopes (Fig. 863 at a), or may pass into the bottom by curves.

In the simplest case the top of the gutter lies directly under the bottom of the beams, the edge of the roof being either placed over its edge or better laid above it. In any case the beam ends and sides between them are to be protected from the water. The best plan is to raise the wall behind the rear side of the gutter, whereby the beams are raised or a low wall is built.(Fig.864

With a more complete construction the edge of the gutter has a balustrade wall or a so-called roof gallery, that in the simplest case would be built later outside the slated gutter, so that its outside continues the slope of the wash and would be covered by a scale-like decoration of the surface.(Figs. 863, 863 .)

Gutters with parapets.

Much richer is the arrangement of tracery balustrades(see later under Tracery); the design requires sufficient width of the upper surface of the gutter for setting the slabs, where the separate pieces are either doweled or fixed by tongue and groove as in Fig. 864. It is preferable in both cases to strengthen the sides of the tongue, and therefore to leave the gutter a projection beyond the face of the balustrade, finished attop

by a wash. The separate parts of the balustrade are accordingly connected at bottom by the gutter in which they are inserted, and at top by the cap laid on them, whose joints must therefore alternate with those of the balustrade. According to the earlier mode of construction the cap of the balustrade is cut on the s slabs and so this connection vanishes and is replaced by dowels inserted in the end joints. The projection of the cap must then be cut at the top of the balustrade and remains at its bottom as a plinth.

Now if we take as the bearing for the beams a width of 36 to 40 cm, the same for the bottom of the channel, and for setting the balustrade 16 to 18 cm, there results for the upper surface of the wall a necessary width of at least 90 cm, which exceeds the dimensions required for the window wall, on which the entire construction depends, and therefore may require it to be increased.

This can be effected inside by corbelling over the top of the compartments, or by an arch about concentric with the side archl externally by those frequently mentioned arches turned between the buttresses as in Fig. 857 b, but most simply by increasing the projection of the cornice. Later will be given various profiles of cut stones producing the same. The upper edge of these members, at least in richer treatment, receives a lower support like that of the bell of a capital, by very varied forms of clever foliage supports, which at the same time compose the most effective ornamentation of the entire cornice, and whose ends generally extend above the face of the edge. As an capitals, they are sometimes connected with a lower row of leaves inserted between them, and are sometimes replaced by these. In Fig. 864 is given the entire construction of such a cornice with balustrade.

Gutter on corbels.

On Burgundian works, those at Notre Dame and the cathedral of Dijon, this piece of cornice is replaced by separate corbels supporting the gutter. On the collegiate church at Colmar this arrangement in larger dimensions is found under the gable of the S. transept, so that here a formel balcony results with a tracery balustrade strengthened by three pinnacles, its bottom slab be ng supported by strongly projecting corbels. Yet these corbels according to the real purpose are far apart and the corbels

are set beneath the joints, in contrast to the more ornamental and closer placing on modern Roman cornices.

In Germany are generally found beneath the roof cornice small corbels connected by arches of many forms, that were derived from Romanesque arched friezes, but receded to a purely ornamental form in the last period.

Construction of stnone gutters.

Stone gutters may be injurious to the walls on which they lie, if the butt joints open or by filtration through the stone of a porous nature. To prevent the first damage, the joints may be cast with cement and at each side cut with a sinking about 1/2 cm deep and 2 1/2 to 4 cm wide in the bottom and sides of the gutter (a in Fig. 865), which is then coated with cement applied on the freshly cut surface, so that this forms a mass with that filling the joint. This is at least a means alone invented by the mason, as practice has taught us. (Note). For greater security may be cut under the joint in the top of the stone beneath the gutter a grrove ending at the front.

Note. The same means is given by Viollet-le-Duc.

Compkete safety from filtration through the stone itself is afforded by careful selection or by placing the channle before the face of the wall and therefore resting on corbels. It may further be sought by a coating of the bottom of the gutter, for which modern chemistry affords many means though not yet tested, and there is generally preferred a lining of lead. This lining that has frequently come into use in restorations in modern times, may easily become very injurious, if the fastening to t the stone is fully secured, which can only occur where the lead sheets must lie on the stone, and must pass beneath the undercut projection of the balustrade.

The water is removed from the gutters by spouts or gargoyles, or by leaders according to the new system.

Spouts.

These either lie at the height of the gutter, so that their channles merely form a bend from the latter (Figs. 866, 866 c), or they belong to a course beneath that (Fig. 867).

In the first case the spout has the form shown in section in Fig. 866 a. On account of the weakening that the stone must suffer at a by cutting off the border, the mass of it must be redu-

reduced as much as possible at the front, and this is generally done by tapering in all directions, only the lower surface remaining horixontal, as seen by Figs. 866 to 866 c. Slope is made by sinking the bottom and the velocity of the flowing water is increased by narrowing the channel resulting from the diminution of the stone. This latter is of special importance, for water dropping too slowly is easily driven by the wind from the vertical back against the wall. The width of the mouth on some later spouts perfectly corresponding to their purpose is 1/3 the width at the junction with the gutter, while in those made not long before and diminished less, this difficulty made itself felt. Likewise the projection of the spout is of particular importance and is generally to be made as great as the stone and other things permit. Special care is to be taken in this if the spout lies above a buttress, and it must then project as far as possible beyond the outside face of the buttress. Thus an undercut before the mouth of the spout (see u) is useful to prevent the water from following back the under surface.

If the outlets lie beneath the gutter, an arrangement offering many advantages, either the raised edge of the channle must be cut away for the width of the outlet channel or the bottom must be perforated. The first arrangement is simpler (Fig. 867) and less exposed to stoppage and can be improved by returning the moulding so far that the exit of the water sidewise is avoided. (Fig. 867 a). In the latter case an undercutting of the sides of the opening is preferable, at least in the direction of the flow of the water.

A reduction of the free length is usually made by the insertion of a corbel beneath, Fig. 869 from the church of S. Maria at Marburg.

The spouts may be arranged in various ways over the buttresses, either independently over their caps, or supported by buttresses. More on this will be seen later. More seldom do they lie between each two buttresses over the middle of a bay, as on the northside of the church of S. Maria at Marburg.

The external form of the spout generally shows only a chamfer bordering the lower angles, likewise diminishing to the front, but returning to the corncie or face of the wall as a rectangle. (Fig. 866 b). On the choir of the foundation church at Treysa

on the contrary are found undiminished spouts on whose lower edges the moulding is broken around and shows its profile beside the mouth (Fig. 868).

Gargoyle.

The richest and most ornamental form of spout is the adoption of forms of animals, with an open channel on the back and neck, that is only closed by the head above like a skull (a in Fig. 870).

The diversity of these so-called gargoyles is sufficientcy known. Starting from strongly conventionalized forms, they ever assume more animated poses, that finally make their function entirely recognizable. The treatment becomes more naturalistic, they partly represent actual animals, but chiefly infernal monsters, sometimes assume human forms, and also sometimes bring out very droll scenes, like that gargoyle in S. Blasien in Mühlhausen in the shape of a cask, whose cock is turned by a little human figure, and usually afford the best place for expressing all raillery. Aside from such humorous representations, many advantages are peculiar to the earlier mode of treatment. That consists of quiet lines better suited to the whole, to their secure location, to their treatment less exposed to injury and their clear expression, to which their function belongs.

In the earlier period the entire figure is seldom expressed, as a rule the rear part being growing out of the cornice (Figs. 864, 870 b, 870 c), or it is shaped like a corbel to support t the body (Fig. 870 b), but always the pose is vigorous, the line of movelenm and especially the neck is beautifully curved (Fig. 864), while in the later time the entirely free beasts with only the rear part combined with the cornice, thus developed in their entire figure with free cut legs and fanciful turns of the heads produce a certain disquieting effect, and the general increase of the amphibious character itself becomes repulsive.

The entire arrangement for the removal of water has an undesirable similarity to the form of the Greek myma. Likewise the water is stored behind the latter and is ejected through the lions' masks with spouts, just as in Gothic architecture by the gargoyle. Only all projection of the lion's mask is avoided, a and the mouth is only thrown beyond the base of the building by the entire projection of the drip slab, since it is treated at the same time to afford that a direct protection from rain.

But the conditions of the possibility of such an arrangement

lies in the predominant relation of the dimensions of the columns and architrave to the height, in the nature of the material and the cilmatic conditions. None of these requirements were g given in Gothic works, the smaller the thickness of the walls did not permit a wide projection of the stone cornice, while t the predominant proportion of the height of the acute angle of fall of rain would have required a proportion far exceeding the Grecian. To protect the lower parts would have required above widely projecting parts that must be more exposed to storms. Therefore that projection is here found only retained for the spouts, even increased in the endeavor to avoid the covering of the face of the wall by the cornice.

Leaders.

In modern times instead of spouts is usually assumed the conduct of the water in vertical leaders of iron or zinc, since in the larger cities this is even required by the police. Yet it has only been successful in very rare examples, to give these attachments a suitable and thus a reasonable form.

On the one hand the unsuitable material in which they are executed is blamed, and yet this in greater part belongs to the custom to allow certain ones to masquerade as not foreseen in the different patterns and standards, or to separate them from the entirety and regard them as necessary evils, where it is better, the less one has to do with them. Hence leaders are usually seen to represent little columns with capitals, flutes, broken cornices, or by natural inclinations under the main cornices and around the different bands with the strangest bends and breaks, which then become leaky, and then assume a brownish yellow coating consisting of dust and rust, interrupting the g gloss of the oil paint. Also the mode of fastening is usually very imperfect, often effected by wooden plugs driven into the joints, into which the points of the separate parts with rings or clips are driven, and also any removal necessary for a stoppage or injury is made difficult in a high degree.

In Viollet-le-Duc is found the construction of a lead leader, that we must mention here in the lack of an example of our own. According to the required length, the entire pipe consists of a greater or lesser number of pieces, that are stuck into each other so that the upper end od the lower piece is outside and below this projection, set in iron wall holders, so that the

number of the latter is determined by that of the pieces, and the projecting edges of these with the irons form a sort of bands of the entire form. The pipe itself is square in section to allow a certain enlargement in case of stoppage, and the lower mouth is formed by bending forward the back instead of an elbow. Below the gutter a basin fixed in the same manner, which also encloses the upper piece of the pipe, just as the separate pieces are set in each other.

According to this system are the pipes made on the sacristy of the cathedral of Amiens erected in recent times. Their connection with the stone gutter is effected in a drily humorous way, with a projecting beast like a gargoyel dropping the water through an opening in its rear into a basin placed beneath it. It thus actually seems that the basin has a small space between itself and the spout, and the latter is generally indicated, n not only as consisting of a hole in the bottom of the gutter, but further that of breaks by belt mouldings is avoided. This can occur in two ways, either according as the cornice or the gutter isppperforated. In the latter case the continuity of the course of the body must be preserved when the stone basin is c connected with the cornice, into which the pipe over it leads the water and from which it runs into the lower pipe. A greater advantage for any repairs would further result, if the pieces of pipe could be separately removed. For this purpose these must not be fixed within each other inside the bent edge, but sufficient play be left that each separate piece can be raised, and if two are raised, one could be removed.

2. Hall Churches.

If the principles of Gothic construction permit the most varied forms of cross section in the measure, that a rich comparison of the different cross sections of churches forms a most interesting study, there may be distioguished in this endless diversity two systems, that indeed pass into each other by a great number of intermediates.

The first system is based on the fact that the thrusts of the vaults of the nave oppose each other in the piers and entirely or partially neutralize each other, and accordingly comprise t the various arrangements of aisles of equal height, the so-called hall churches, the second system or so-called basilican plan exhibits a raised middle aisle, and opposes the thrusts of the

vaults by a means of resistance produced in a different manner.

Under the designation of hall churches may be comprised all two, three or more aisled churches, whose vaults have exactly or approximately equal heights. Churches with two aisles have already been more nearly described in regard to plan (p. 276 to 282), which did not there explain the peculiarities related on one hand to the cross section of single-aisled and on the other to that of two-aisled churches. Also the cross sections of five-aisled churches (see p. 289 on these) refer in most examples b back to three-aisled, that will alone be mentioned in the following.

Churches with four aisles belong to the oddities, taking as an example the parish church at schwaz in the Tyrol with four-aisled nave covered by a common roof. As another exceptional f form may be mentioned here the five-aisled western portion of the Late Gothic church of S. Barbara at Kuttenberg, whose three middle aisles rise as an ordinary hall church above the outer side aisles.

General conditions of stability of the hall church.

Aisles of equal width.

When the three aisle vaults exhibit equal spans, heights, and further the same forms, there are the same conditions of stability already developed for the plan with two aisles, i.e., the dimensions of the detached pier are chiefly determined by the vertical load and thoseof the external wall by the thrust of the vaults of the outer aisles, entirely independent of that of the middle aisle. Therefore the outer wall is to be constructed exactly the same as for a single-aisled church with equal thrust of the vaults (p. 235). At most the wider roof may add other requirements by its different construction and the greater wind pressure that in the same case demands somewhat thicker external walls and their buttresses.

If the middle piers receive no roof load, and by sufficient resistance of the outer walls struck by the wind are not notably affected by the wind, then as stated, their dimensions only need to be determined by the quiet vertical loads resting on them (p 278), and these may then become quite slender. On the contrary if the piers are affected by roof load or wind, they must either be correspondingly strengthened, or the vaults or cross arches over them must have in themselves sufficient stiffness to conduct all thrusts to the strong external walls (Figs. 412, 413).

A fine example of a plan with three equal aisles is afforded by the church of S. Maria at Herford (14 th century).

Different widths of aisles.

For different widths of the aisles, assuming a similar kind of vaults, the thrust of the wider, usually the middle aisle, exceeds those of the narrower aisles, and therefore above the pier is only a partial equilibrium of the thrusts, and the surplus must be assumed to be transferred to the side aisle, whereby three possibilities result.

1. The middle piers are so strong, that they alone can receive the surplus, and only the thrust of the side aisles comes to the outer walls.

2. The surplus thrust is partly taken by the middle piers and partly by the outer walls.

3. The middle piers are relieved from this as from all thrust by suitable means. The thrust against the external walls then becomes as great as the thrust of the middle aisle. Therefore in this last case the external walls are to be made correspondingly stronger than in the first two cases.

It was formerly the opinion that the first case always existed, i.e., that the surplus of the middle thrust must be resisted by the pier. The vaults of the side aisles were held to be unable to transfer thrusts. But thereby could not be sufficiently explained the extremely slender middle piers of certain churches and on the other hand the excessive dimensions of the buttresses, and in regard to the latter a certain extravagance was attributed to the old masters.(This view is also found in the earlier editions of this manual. Second edition, p. 455, 456).

But now it was sufficiently shown above (p. 168), that the cross vault already could stiffen transversely or transfer thrusts by the peculiarity of its form in contrast to thin tunnel vaults. Where this did not suffice, the end was attained by a stiffening of the transverse arches (p. 169).

This property of the vault did not escape the ancients' as in other places, they frequently utilized it in hall churches, where it was employed to reduce the middle piers. This is shown by the form of the vaults in many works and still more by the contrasted ratio of the dimensions of middle piers to the buttresses.

Accordingly middle piers and buttresses take the places of each other to a certain degree, and one can be made smaller if the

other is correspondingly strengthened. This is shown by the monastery church at Haina, that has only thin outer walls and very strong middle piers, while in many other examples, Friedberg in Hesse, Viener-neustadt, Kuttenberg, etc., the external walls are conversely strong in comparison to the light piers.

To place the dimensions of the middle piers and outer walls in a definite relation to the clear width of the aisles must a appear absurd with the varying conditions of stability, but in the old examples the width of the middle pier varies between t the wide limits of about 1/3 to 1/12 of the middle aisle (as a mean between 1/6 and 1/8), and the external buttress including the thickness of the wall varies from 1/3 to 1/1 of the width of the side aisle (averaging 1/2 to 2/3).

Stability of the middle pier.

As just stated, the difference between the thrust of the side aisles is either received by the middle pier if made sufficiently strong, or is entirely or partially transferred to the external wall and its buttresses. In most cases it will be treated thus; relieving the middle piers of the thrust as much as possiple, there are three ways possible:- 1, the vaults of the side aisles are made to thrust so strongly by their flat form or great weight as to neutralizs the thrust of the middle aisle; 2, the side vault still remains light but is made stiff, i.e., it receives a form making it possible for flatter lines of pressure to be formed in it (in cross vaults lying in the vicinity of the crown or in the cross arch, p. 168 to 169); 3, over the side v vault and separated therefrom is assumed a stiffening of the middle aisle from the external walls. This plan is only possible with tolerably high middle aisles and leads to the buttress system of the basilica. The height of the vaults with regard to e each other plays a great part everywhere in neutralizing the thrust.

The vaults of the side aisles can begin at the same height as the middle vault (Figs. 350, 351), it can be raised or stilted above them (Fig. 352), or it can be placed lower (Fig. 354). These different heights of vaults in any combination with one of the just mentioned transmissions of the thrust produce the different cases of stress in the middle piers. The most important of these were represented earlier in Figs. 350 to 355 (also see the corresponding text, p. 127), and they may be comprised

in the following.

Very thin vaults in side aisles.

a. The vaults in middle and side aisles commence at equal heights. The most unfavorable case occures when the narrow side aisle vaults are carried in slender lancet form to the same height as the wide middle vault (Fig. 350), the difficulty indeed increasing with the difference in width of the vaults. It is to be seen from the sketch in Fig. 350, that the intersection of the vault thrusts does not fall in the middle of the pier, but is unfortunately nearest the side vault. Moreover the resultant of the thrusts is very steeply inclined, so that the pier must have a great width to surely contain it downward. If the side aisle is quite narrow, the pier thus requires nearly the width which it must have if the vault of the middle aisle alone existed.

A transfer of the thrust over it to the outer walls is here but imperfectly possible, for a thickening of the side vault w would only be very unsightly, and could only be executed with care that the slender form (Fig. 127 D), by the placing of masses on the otherwise readily executed vault or on its cross arch, and a stiffening of either the crown of the vault or of the oross arch could only reach the upper part of the middle vault, and therefore could not prevent the middle vault from always placing a considerable portion of this thrust at the height of the springing.

Similar proportions of rise in the aisles.

Much more favorable are the side vaults when their proportion to rise is made less, so that they correspond to that of the g great vault ($\frac{f}{b} = \frac{1}{13}$ in Fig. 351). The thrusts for equal thickness of the vaults are then about as the spans. The intersection of the thrusts is less distant from the middle (of the pier) and the resultant is steeper downward. Moreover for a great difference in widths of the aisles the pier must have a considerable width, if it must alone receive the excess of the thrust of the middle aisle.

Construction of the line of support or a calucaltion can be made more simply by taking the thrusts from Table I, p. 135, t that will give data thereon. On p. 154 is given an example of such a calculation. (Read there in line 20 from bottom, 6 m length of bay instead of 9 m, also p. 155, line 21 from top, sq. m instead of sq. cm).

That for such a ratio of rise (Figs. 351, 394) it is easily possible to obtain equilibrium of the thrusts by loading the side vaults or by their stiffness.

On p. 157 is given for the same example, how to make equilibrium possible by building a wall on the cross arch, and to bring the dimensions of the middle pier to a minimum. For this example would be required 8 cu. m. of split stone, which is to serve not for stiffening, but only as a quest load and therefore can be set irregularly. If instead of this stiffening by the cross arch is intended, then a smaller volume would be laid on it, b but which is to be laid in fixed bond, so that the carrying over of a flatter line of support would be possible. Best is an intermediate step, the wall that has special reference to stiffening but on the contrary usually acts rather as a moderate load.

Which of the many possible lines of support actually exists in the wall again depends on the mode of execution, etc. Since with a good wall mass one can count on a certain elasticity or even plasticity, it must be assumed that the force and resistance are to be directly equilibrated as far as possible, In the present case there acts at one side the middle aisle with the force I in fig. 871. From the other side acts the thrust II of the side vault, but which on account of its lesser magnitude a and lower position cannot equilibrate the force I. The middle of the mass of the wall will be inclined upward to the left, which carries a reaction of the wall on the cross arch in itself, and as a consequence the formation of the line of support III in itself. This line of support is so formed in location and magnitude of force, that it combines with II to produce a resultant line IV, which may exactly equilibrate the force I. So long as the wall on the cross arch is so built, that a free development of such a line of support III is possible, can occur an equilibrium of thrusts over the pier, the latter will receive a vertical or very slightly inclined pressure. If the line of support III corresponding to the requirements in the wall is impossible, then is the mass or form to be changed, which can be done by m means of a graphical or mathematical investigation. If the equilibrium of thrusts is but partially obtained, then must the excess be overcome by the middle pier correspondingly enlarged.

If there also occur over the pier roof or wind loads, then

the vertical component of these is usually not

not inconvenient but desirable, but the horizontal forces are also to be investigated, how and how far they can be received above, or must be supported by the pier itself.

For every change in the thrusts the line of support III moves up or down, is more or less strongly curved, so that always the equilibrium most possible occurs, and in this way equilibrium is always preserved in variations of the wind.

Vaults stilted at the sides.

b. the vaults of the side aisles are stilted (Fig. 352). Stilting the side vaults was employed in nmmerous hall chauches of the Early aud later Gothic, and there are mentioned as examples the Early Gothic churches of Hesse at Wetter and Haina, the church of S. Elisabeth at Marburg, the churches at Friedberg and Frankenberg (Fig. 872), as well as the later church at Neustadt near Marburg (Fig. 873), and of the many examples in Westphalian and lower Saxony are taken the cathedral at Minden and the Alexander church at Einbeck, and finally may also the Benedictine church at Oedengurg (beginning of 14 th century), also the church S. George at Wiener-Neustadt, and the Piarists' church at Krems may find mention in Austria-Hungary.

The vaults of the side aisles usually rest on the same capital whth those of the middle aisle, rarely above the latter. The stilting is characterized by a little cornice moulding (Einbeck), sometimes also the capitals of the rounds in the side aisle are lowered to the height of that of the rounds of the middle aisle (Fig. 889), and finally the late examples exhibit a development of the members at different heights without capitals (Fig. 873).

Stilting first has the purpose of elevating the crown of the narrower vault so high that it may rest against the dividing arch at the same height as the middle vault, but it also has besides the structural advantage, that it favors the stability if the middle pier. This particularly appears by a comparison of Figs. 350 and 352. A small stilting of about 1/4 the difference of the two spans already presents an advantage, that the horizontal thrusts occur at the same height (H_1 and H_2 in Fig. 394); it is thereby attained that the total pressure on the top of the pier begins at about its middle. If the stilting be higher as shown in Fig. 352, the intersection of the inclined thrusts of the vaults at the side of the middle aisle, the pressure in the pier that always passes obliquely downward can therefore at bot-

bottom not so easily pass to the outside edge next the side aisle. It follows from this that with the stilting in Fig. 352 the pier can be made considerably narrower than with the lancet arch of Fig. 350. The stilting will not be carried too high, since otherwise the pressure on the pier at top would be found too close to the inner edge, which might at the height of the springing in the middle aisle produce crushing of the stone or a buckling of the pier toward the side aisle, as in fact is observed in the church at Neustadt. (Fig. 873). In such cases it man be an advantage to corbel out a strengthening round above inethe middle aisle.

With the aid of a proper stilting may thus be obtained a favorable transfer of the pressure and consequently a certain reduction of the mass of the pier, but the pier must always remain sufficiently large to receive in itself in great part the difference of the thrusts in the vaults. A transfer to the external wall above the stilted vault is just as difficult as over a lancet vault (see above). It is necessary to effect such a transfer, since men desire to make the middle pier still smaller, or since roof or wind loads are to be received, the end is best reached if the vaults begin at the same height (Figs. 351, 353, 374), or even if the side vaults are lowered (Figs. 354, 355).

By graphical or calculated finding of the line of pressure in the pier, it is recognized that the thrust of the stilted vault (including all extra walling etc.) must always remain smaller than the total thrust of the middle vault, and it must at most increase so much that the horizontal thrusts are inversely as their heights above the base, thus in Fig. 873: $H_1 : H_2 = h_2 : h_1$.

h_1 Lower side vaults.

c. The vaults of the side aisles commence lower than the middle. Already with beginnings of both vaults at equal heights it may occur, that a difference in the height of the dividing archmakes itself felt, as in S. Laurentius at Ahrweiler, Fig. 890. This will be greater if the side vaults commence lower (Fig. 888). The height between the crowns of the two vaults is closed by a dividing wall, that is borne by the dividing arch, and must be so strong as to be able to receive safely all thrusts produced by the vaults, roof or wind without overturning or bulging (p. 130). If it be not sufficiently resistant by its own thickness, it must be stiffened to a greater or lesser height, whether be-

below or above the roof surface.

If the upper side wall is sufficiently safe, then is concerned the stability of the pier,. The most unfavorable case occurs w when the narrow lower aisle is covered by a light and not stiffened vault, for example a continuous tunnel vault, and this w will so little oppose the great and higher located thrust od t the middle aisle, that the pier requires those great dimensions, which are actually shown in such Romanesque works. If the pier is made too small, then the side tunnel is raised at the crown and broken, whereupon the pier itself is overthrown. By a rampant half tunnel vault men sought to obtain the stiffening applied higher and more effective, but first found the solution when cross vaults were employed over the side aisles. Cross vaults made it possible to form an important transverse stiffening in the flat upper parts (Figs. 412 and p. 168), thereby entirely or partially equilibrating the greater thrust of the middle aisle, thus so greatly relieving the middle pier from this thrust, that it could be made considerably thinner. Cross arches with flat crowns are better suited for this stiffening than swelled or even melon-shaped vaults. The thrust so transferred by the upper parts of the side vault strikes the upper part of the external wall and by the stability of that, etc., can be accepted as sufficiently secure (p. 340).

If one does not wish to trust entirely to the stiffness of the vault, there remains a loading or stiffening wall on the cross arch (Figs. 343, 344).

The loading of the cross arch can be carried very far, since it is favorable to the stability of the pier, that the thrust of the lower lying side aisle is greater than that of the higher middle aisle, the lower the side vault is placed, the greater is to be made its thrust. In many cases it is well permissible to place a solid transverse wall on the cross arch, that extends to the crown or beyond it, and it can terminate horizontally or rise obliquely toward the middle aisle. If it be too heavy, it is to be opened (Figs. 888, 355).

The course of the pressure is about the same as given in Fig. 401 for a simple basilica. If the total thrust of the side aisle exactly equaled that of the middle aisle, the pressure in the pier between I and II would be vertical; if the side thrust is least, the pressure would tend toward the outside, if it were

greatest, as in the drawing, the pressure would tend to the inside. The last leads to a more central location of the pressure below in the pier and therefore is usually most favorable. The wall on the cross arch will prove too great, if even with the assumption of a steep pressure curve in it (II in Fig. 871), the pressure in the pier drops too much toward the middle aisle. As an approximate check may it be assumed, that the magnitude of the thrust should be inversely as its height above the base. This rule is about right if the loads are all placed as nearly central as possible over the pier, by a projection of the loads to the right or left the stability is substantially affected, indeed favorably if the masses are adapted to the course of the pressure as nearly as possible.

In variations of the pressure of wind, etc., (further see later), equilibrium must always be still possible for the limit cases, and this is still to be regarded as existing, if any needed flatter or steeper line of pressure freely makes possible equilibrium of forces above the pier, that the latter is not drawn inaccurately in sympathy; just for these cases do not approve too heavy by stiff walls over cross arches or flying buttresses for greater heights.

Stability of external walls; effect of roof load and wind.

The stability of the wall with its buttresses must first suffice for all effects of the thrust of vaults, and then also with the contemporary occurrence of roof load and wind, first let the thrust of the vault be considered.

Stability against pressure of vaults.

It has already been shown how the dimensions of middle piers and of external walls may take the places of each other. If the middle pier is so large that it can itself receive the difference of the thrusts of the vaults, only the thrust of the side aisle falls on the outer wall; if the middle pier only takes a part of the difference of the thrusts, the remainder passes to the external wall, whose thrust is between that of the side aisle and that of the middle aisle. On the contrary if the middle pier is kept entirely free from thrusts, then with correct construction the wall must expect a thrust that about corresponds to that of the middle aisle, and indeed with stilted side vaults will generally be somewhat less (p. 372), while with side aisles

placed low it may exceed the thrust of the middle aisle (p. 373, above).

Farther above for the hall churches represented in Figs. 394, 395, were calculations made for the middle pier for two different cases of the middle aisle, that according to the assumption there had to support no roof load, but only dividing arches and vaults. In the first case (Example I, p. 154) the pier was just strong enough to bear the difference between the two vault thrusts, and therefore the external wall had to take into account only the thrust of the side aisle. In the second case (Example II, p. 157), where the treatment was to reduce the middle pier to a minimum size, the external wall received a thrust (H_2 + H_3 = 2160 + 1186 = 3346), which almost exactly corresponded to the thrust of the middle aisle (H_1 = 3240). For this thrust was the outer wall to be calculated like the external wall for a single-aisled church (Example on p. 336).

Effect of roof construction.

In regard to the roof load and also the wind pressure, that is intimately connected therewith, the support of the roof beams is of great importance. Clearest are the conditions when the roof framework rests only on the outer walls, while the pier a and dividing arches are entirely free. One cannot then state as entirely determined how the horizontal wind pressure is divided between the two supports, but however the general idea is much clearer than if a greater number of supports existed.

If the roof rests at the same time on the outer walls and the middle piers, the most unfavorable case would exist, and besides no stiffening connection between the piers or their dividing arches exists there and the external walls. It then depends entirely on the nature of the roof construction and the direction of the resulting stresses how the forces are divided among the separate points.

It may be added, that in such cases a bad truss already of itself exerts a thrust aside from the effect of the wind, and by its great height may act very unfavorable on a support, whether a wall or a pier; it is not at all improbable that this same s support may also have to receive the greatest part of the wind pressure on the roof (greatest on hall churches). If it be the external wall, then if insufficient in thickness cracks and bulges soon appear, which are particularly enlarged by great storms;

if it be an insufficient pier, then will it be crushed and the vaults be placed in cross stresses, so far as this is possible, transferring a part of the excess load to the nearest supports, that on their part must be sufficiently stiff. It is then of g great use, if at least strong walls exist on the dividing arches, that these can carry the side forces to the crowns of the vaults, which they will transfer farther as well as possible. Moderate side forces can thus be very well passed through the crowns of the vaults, but very great wind forces require there a constant and important composition of the stresses, which may lead to injurious loosening of the joints in those parts of the wall and vaults. It is best again to resort here to stiffening cross arches, as we shall see.

Stiffening by roof trusses.

Roof framework on lower beams extended across are mostly usable over aisles of equal height (Fig. 876), and almost completely prevent those injurious effects. They receive the thrust of the roof timbers and make it impossible for the wind pressure on t the roof to be transferred to single supports. The entire effect of the wind is carried to the beams, and seeks as a whole to t thrust in their direction. On their part the beams tend to press on all supports beneath them, and indeed the weaker supports t thus receive less thrust, since they are quicker to yield (Fig. 838 a), and on the other hand the stronger supports will later oppose it and consequently receive the greater part of it. But that is extremely favorable; hence one can count on through beams that the wind pressure against the roof will be distributed among the supports (piers and walls) about in proportion to their resistance. The wind against the roof cannot injure the structure, if the stability of the supports in general has sufficient safety.

On account of clearness, only the wind against the roof is m mentioned and not the wind pressure on the outer wall, but the last produces an overturning moment (pressure × middle height of exposure), which must also be safely received. This wind pressure to which is opposed the thrust of the vaults can be mostly taken by the wall affected; where this is impossible, a part must be carried to the nearest middle pier or even across all three aisles to the opposite outer wall, which is to be done through the crowns of the vaults or stiff cross arches, or less

well also through the roof beams.

Stiffening by the cross arches.

A stiffening wall on the cross arches is the most reliable and monumental means for making possible any transfer of thrust, a and it is especially in place where through roof beams are wanting; it was very frequently employed by the ancients. The wind need only be opposed by the adjacent middle piers, and a wall on the side cross arches suffices; on the other hand if a greater opposition of the thrust over the entire width be possible, the middle cross arches are to be stiffened also. On the latter the walls are to be made as light as possible, not to increase the thrust of the middle aisle unnecessarily, and thay may therefore rise obliquely toward the crown (Fig. 87, a) or be perforated (Figs. 875 b, 413). The thickness of this upper wall is sufficient if 1/15 to 1/30 of the span, and for brick it is seldom necessary to go beyond 1 or 1 1/2 bricks.

Such a stiffening wall can receive in itself the different lines of pressure and will be more effective than through beams, since the side forces are distributed to the supports in proportion to their resistance. Particularly with a correct arrangement of the masses employed, the middle piers can be entirely freed from side thrusts, so that they onlyneed to bear the vertical loads by the aid of their resistance to compression and bending, and therefore also with equal widths of aisles can be made quite slender. Indeed they could be replaced by iron columnswith pivot joints at top and bottom (Fig. 875), or what is about the same, by slender granite posts so arranged by their ends, that no pressure can occur at the angles.

Investigation of the wind stresses may be graphical, whether the piers be only compressed or thrust, but more simply by calculation. By the last column of the Table on p. 108 is found t the magnitude of the wind thrust acting on the roof at all supports, and this multiplied by the height above the ground is t thus the overturning moment to be resisted. This is the moment exerted on the wall by the wind pressure. Now is to be calculated what overturning moment can be resisted by each separate support (pier or wall). For this purpose is calculated the position of the pressure at the ground with any thrust of vaults and the vertical loads (p. 155, 336), and it is now to be seen how far the pressure in the direction of the wind can still move

without coming too near the outer edge. This distance multiplied by the entire vertical load resting on the ground gives the overturning moment which the support can yet receive. The sum of these moments received by the separate supports must exceed the actually acting overturning moment.

Examples of calculation.

Example I. For the hall church represented in Fig. 394, whose piers are sufficiently strong according to the evidence of the calculations on p. 155 to receive the excess of the thrust of the vaults, the stability of the external walls is to be investigated, with and without wind pressure.

The plain external wall is 20 m high and 1.7 m thick with a window of 30 sq. m area in each bay and is built of coursed split sandstone, weighing 2300 per cu. m.; a bay of the wall accordingly has (20 × 6 - 30) × 1.7 = 153 cu m. volume and weighs 153 × 2300 = 351,900 kil or in round numbers G = 352,000 kil.

The thrusts of the vaults (without stiffening of the cross arches) are given on p. 154, and it is for the external wall as a vertical force V_2 = 6840 or in round numbers ≈ 7000 kil, but w with regard to the possible transmission of force from the middle aisle here, as a thrust H_2 = 2160 kil, this will be increased to 2500 kil; it is located 13.2 m above the ground.

The roof with an inclination of 55° has a slope 20 m long, thus above each bay an area of 2 × 20 × 6 = 240 sq. m (p. 162), hence altogether = 240 × 90 = 21,600 kil.

The wind against the wall at 120 kil per sq. m has a horizontal force of 20 × 6 × 120 = 141400 kil, with a mean height of application of 10 m. According to p. 163, the wind against the roof exerts a vertical pressure of 57 kil and a horizontal pressure of 81 kil per sq. m, thus on the entire 120 sq. m of the roof surface 57 × 120 = 6840 kil vertical pressure on all supports together, and 81 × 120 = 9720 kil horizontal wind thrust, that acts on the support 20 m above the ground.

A. Locatio of pressure in the wall without roof load and wind. The location of the pressure in the ground area of the middle pier was already calculated on p. 155, and it lies 20 cm from the middle of the pier toward the outside.

The pressure on the ground area of the external wall is found according to p. 140 (Fig. 371) by establishing the equation of moments for the unknown pressure point distant x m from the inside.

$$V_2 \times x + Q\left(x - \frac{1.7}{2}\right) = H \times 13.2$$

Or $700\,x + 352000(x - 0.85) = 2500 = 13.2$. Thus $x = 0.93$ m.

The pressure therefore strikes the ground area at a distance of 93 cm from the inner side or 77 cm from the outer side, and thus is only moved 8 cm from the middle toward the outside. The maximum pressure at the outer edge is found approximately by t the Table on p. 145, more accurately by formula 5 on p. 143, a and is calmulated by this at:--

$$p_1 = \frac{352000 + 7000}{600 \times 170} + \frac{(352000 + 7000(\times 8}{1/12 \times 600 \times 170 \times 170} = 4.5 \text{ kil per sq.cm.}$$

Therefore the pressure usually falls at a very favorable place and produces only a moderate edge pressure and remains very small, even if with regard to the window opening the entire length of 600 cm of wall is not considered as supporting. The addition of the weight of the roof without wind scarcely changes the result.

B. Location of the pressure with full effect of wind (120 kil per sq. m). The wind against the wall produces an overturning moment of 14,400 × 10, which must be opposed by a moment of stability of y × (352000 + 7000), from which is calculated, y × 359000 = 14400, and thus y = 0.40 m.

I.e., the pressure falls about 40 cm farther in the direction of the wind, so that instead of being 93 cm from the inner side it is now only 53 cm from it. Then the maximum pressure at the inner angle is, according to formula 6 on p. 144, since it lies outside the kern of the section:--

$$d_1 = \frac{2(352000 + 7000)}{3 \times 600 \times 53} = 7.5 \text{ kil per sq. cm.}$$

Therefore the wall can very well resist the wind acting on it, and it can even receive a part of the wind thrust on the roof.

The wind against the roof produces the great overturning moment of 972 × 20 = 194,400. This can be assumed to be neutralized by the external walls and the middle pier at the windward side, since these wind and vault thrusts oppose each other. For the middle pier that with a moderate addition for the roof load weighs 75,000 kil, the removal of the pressure may be taken at about 35 cm, and then 75,000 × 0.35 = 26,250 and be taken ar t the overturning moment, since its remainded of 168,150 m-kil is to be borne by the external walls. If to the weight of each wall is added an average but concise addition for the roof load of 5000 kil, the total load is:-- 352000 + 7000 + 5000 = 364000 kil. The moment of stability to be exerted by the walls must equal the overturning moment:-- Thus $364000 \times y_1$

$$\frac{3 \times 10^{10}}{\quad} = 3.3 \text{ sec per cm.}$$

$$\text{per cm.} = \frac{\quad}{3 \times 10^{10}} \text{ sec}$$

thus 364000 × y_1 + 364000 × y_2 = 168,150. Hence results $y_1 + y_2$ = 0.46 m.

Hence in both walls the pressure must be moved about 46 cm in the direction of the wind; if 11 be reckoned for the wall affected and 35 for the other, then in both the pressure acts equally near the edge, namely at (77 - 35) or 53 - 11) = 42 cm. The edge pressure will then be according to formula 6 on p. 144:--

$$d_1 = \frac{2 \times 364000}{3 \times 600 \times 42} = 9.6 \text{ kil per sq. cm.}$$

This stress seems not too great for good coursed brick masonry, it it is remembered, that such an effect of the wind is extremely rare, perhaps never occurring during the existence of the b building. (Note). The small removal of the pressure from the k kern is also inconceivable in these circumstances. Likewise a less uniform distribution of the thrust to the walls would not make much difference.

Note. The static proof required by the police officials for the construction of buildings, heretofore usually neglected the effect of wind on masonry, which is however an excentric direction of the pressure, and it would be proper to extend the limits of permissible stress, where these moments are accurately considered. Perhaps it might be advisable to set two limits, one for permanent loads, the other for those seldom occurring and perhaps for stresses only after complete hardening of the mortar.

Example II. For the same hall church are employed very ulender middle piers and walls placed on the cross arches.

The calculation that will not find further space here quite corresponds to the former, except that the thrust of the wind against the external wall is greater, and the wind is alone to be received by the outer walls without the aid of the middle pier. The thickness of the wall previously assumed also shows itself as sufficient for this case. If the roof framework rests on 4 points (piers and walls), only two of which as the walls must receive the wind thrust, then a slight anchoring to the l latter may be proper, especially for very steep roofs.

For simplicity a plain external wall is assumed in these examples; if the wall has offsets and buttresses, the investigation would be the same on the whole, as shown by a glance at the corresponding calculations for a single-aisled church (p. 337).

Roof of hall church.

As the design of the vaults is decisive for the interior, so

is that of the roof for the e?terion of the hall church. But b both designs are related to each other and exert a certain reciprocal action on each other.

If we assume at least an approximately equal height of the different crowns of the vaults, then would the design of the church at Immenhausen represented in Fig. 876 be nearest, that exhibits a roof with continuous truss beam extending over the three aisles, There the intermediate rafters stand as hammer beams and they form with the walls placed on the dividing arches a further support of the framework of the roof. Here the difficulty in finding timbers of sufficient length for the truss beams may lead to placing them only over the middle aisle, and the beams necessary over the side aisles resting on leveled dividing arches and on the sills anchored by the middle beams. T This connection can be made in different ways, and also the arrangement of a common roof over three aisles of unequal height of crown. Then the through beams over the side aisles either take an inclined direction as in the left half of Fig. 877, or like the construction found in the right half of Fig. 877, or where are the beam a, post b, sill c and again the beam d, the wall plates being anchored by these. Accordingly the topcof the wall of the side aisle lies lower than the crown of the vault of the middle aisle, and this extends into the roof.

If the design of a common roof over the three aisles is simplest and affords certain advantages in the removal of water, t then for the external effect it is most unfavorable and corresponds least to the proper character of the cross section. This lack of expression already appears in the concealment of the design in three aisles, and even more the junction of the roofs of the choir and that of the nave only to be obtained by powerful ways or by certain expedients. This junction would first require an attic of the nave terminating at the east with a closing bagle wall, either having the choir roof at the same height as in Fig. 878, or joining it with the same inclination. In both cases would be necessary either a strengthening of the triumphal arch to receive the wall triangle a b c or the corresponding lozenge surfaces, or the arrangement of a pointed arch turned beneath the roof of the church in Fig. 876. To avoid the latter is then found separately only the triangle a b d through the wall, so that the masonry and wooden wall lie under the edge of the

gable. Then further sometimes the wall triangle a b d is removed and the entire triangle d a c is closed by a wooden wall. But it is more correct to form the eastern ending of the nave roof by a hip roof, into which the choir roof intersects (Fig. 879). The last design is almost requiref by high side choirs carried high. If there remains a reentrant angle a c b , let the latter and the high choir, as in Fig. 880 on which rests the straight through eaves of the roof (Fig. 881). With equal longitudinal extension of all choirs is then given the means most usable on the brick churches of Baltic countries, for further simplification of the roof, and even for the design of an eastern gable corresponding to the entire width of the nave.

Likewise the junction of the roof of the single-aisled transept to that of the three-aisled nave leads to the most varied designs, according as the height or inclination of both roofs is the same. In the first case the roof of the nave extends to the western, and the roof of the choir to the eastern roof of the transverse aisle (Fig. 882). In the second the eastern roof of the cross aisle may extend in a hip of the roof of the nave or the latter can intersect the roof of the transverse aisle a and be connected with the choir roof in one of the ways mentioned above (Fig. 883). An arrangement certainly bearing the character of a makeshift is found on the choir at Wetter (Fig. 884), where the roofs of the nave and choir have equal heights and have the same inclination as the roof of the transverse aisle, so that the oblique surfaces a b c d join opposite the latter. (This arrangement results from a later alteration).

The magnitude of the roof surfaces makes their ornamental treatment appear desirable, that can be made either by the number and form of the openings, or if the material permits, by patterns in several colors. For this design are suited all materials used for covering the roof, so far as the conditions permit them to be obtained in different colors, but especially glazed tiles. Very rich examples of this kind are found on S. Stephen in Viennaand on various churches of Burgundy, of which we give in Fig. 887 an example from S. Benigne in Dijon after a hasty sketch, for whose primitiveness we cannot answer indeed. (There are indicated white, yellow and light gray, red and dark gray, green and grayish black, and black). Least adapted to such treatment are the different metal coverings. Yet very rich effects are

produced by partial gilding, by the location of certain plates, by the form of the openings and by the design of the existing crowning of the ridge.

Longitudinal roof over each aisle.

But the arrangement of the common roof suffers in the main d defects, that it is only connected with the form of the whole and does not result from that. Yet the latter condition decidedly occurs in the covering of the didderent aisles by three parallel and longitudinal roofs (Fig. 885), between which lie gutters from which the water either flows lengthwise at west and east through spouts, or is led to both sides by special channels beneath the roofs of the side aisles, a plan which of these expedients relating to the junction of the roofs of the choir and transepts make indispensable.

Transverse roofs over side aisles.

Those covered channels beneath the roofs of the side aisles are then changed into open ones by the arrangement of separate transverse roofs over the separate bays of the side aisles with gutters over the cross arches separating the latter, which either extend as hip roofs to the roof of the middle aisle or may intersect it (Fig. 886). Particular care is to be taken always in the construction of the gutters. They must be as wide as possible, accessible from the roof of the middle aisle, be made of heavy lead and extend at least 6 to 8 inches under the covering of the roof; but in the upper wall connected therewith lies the only defect in the entire design, which in other respects is to be termed the most complete, as it is found on the best works with aisles of equal height. We mention here the church of S. Elisabeth at Marburg, further the cross church at Breslau, S. Blasien in Mühlhausen and the church at Friedberg. It existed on S. Alexander at Einbeck and was originally intended on the monastery church at Haina anf S. Maria at Mühlhausen, as may be clearly recognized. In the last case only on account of cheapness, it was changed into the plan of the common roof covering all aisles, whose sole advantage consists in its ecomony. However the last also fails, when a sufficient substitute was found for the lead gutters. The outer ends of the transverse roof can be closed by hip roofs or ordinary gables.

Middle aisle of greater height.

Middle aisle continues in an attic.

When the design of the roof just described results from the section of the vaults, then conversely the form of vaults as s shown in cross section in Fig. 888 will lead to the adoption of quite different heights of vaults in the three aisles. Thus the dividing arches lie at the height of the vaults of the side aisles, but on them are built walls, solid or opening into the attic, carried to the height a that are adjoined by the side arches of the vaults of the middle aisle.

The entire arrangement is preferably executed in limited proportions. In larger dimensions the faulty lighting of the middle aisle is still injurious, although the contrast with the brighter light in the choir has a picturesque effect.

Middle aisle rises above the roof.

The difference in height of the aisles can be reduced by giving the roofs of the side aisles a flatter inclination than that of the middle aisle, thus forming a break at the latter (right half of Fig. 888). Since the unity of the roof is broken, the unequal heights of the aisles, the upper wall of the middle aisle above the junction of the roofs of the side aisles extends up in the form of a frieze separating the two roofs (Fig. 888 a). A further elevation of the middle aisle with this part of the then leads to opening it by windows, and thence to the fully expressed system of the clearstory of the middle aisle, so that the design in Fig. 888 in a certain way occupies a middle position between the hall church and the basilica.

Separation of the middle aisle.

This intermediate position is more decidedly expressed in the structural relations of the vaults and piers. The entire arrangement of the cross section as shown comprises, that a direct opposition of the thrusts does not occur, and therefore a resistance is to be provided against the thrust of the middle aisle, either by strengthening the aisle piers or by any other plan. To this belongs the erection of abutment walls on the separate cross arches dividing the side aisles. The latter then require a stiffening while those walls are carried up beneath the roofs of the side aisles and enter into their construction, i.e., can receive the purlins. The necessary communication of the attics over the separate bays, or the reduction of the masses for static reasons (p. 128) then requires an opening in this abutment wall, whose design is to be such, thaa at the height of the

point of application of the thrust of the vault of the middle aisle remains a sufficient thickness to prevent the sliding of the separate courses and therefore the bending of the piers, i. e., the total thickness a b + b c in Fig. 888 is sufficiently large, or the opening must be arched in circular form. These w walls can then fulfil a twofold purpose, for then first ensure by their weight the unchangeable line of the cross arch, i.e., prevent any bending of it upward and thereby an overturning of the aisle pier outward, but then conduct the thrust of the vaults of the middle aisle to the buttresses standing in the outer wall, and in a sencs form a shoring of the parts of the wall exposed to this thrust. The load on the cross arches must not be too great, since otherwise the piers would be forced inward too strongly. (Further on this on the preceding p. 373).

If follows from this that those walls can furnish under certain conditions the before mentioned utility of a separation of the aisle pier, but that its construction as soon as it becomes too heavy easily becomes faulty, and is better replaced by one that avoids the loading of the cross arches, and that is the use of the buttresses lying under or over the roof, to which we shall all return later.

Relation of heights of choir and of middle aisle.

The choir and the middle aisle have the same height as a rule. Variations are indeed often found, partly resulting from the s system lying at the ground of the entire design, partly are changes from the original design as the consequences of an interruption of the construction. Thus a greater height of the nave, according to the arrangement of the system of vaults results f from the plan of two-aisled choir as found in a particularly striking way in the church of Niederaspe near Wetter in upper Hesse. For here the beginning of the arches extends from the m middle row of piers and the cross ribs from the same point rest on the keystone of the triumphal arch, so that the crown of this arch and of the choir vault drop to the height of the basis of the vault of the side aisle.

Likewise in single-aisled churches with narrower choir, the unequal spans of the choir and nave vaults on a common basis lead to a lesser height of the former, as the cross section of the Minorites' church of Duisburg shows.

Conversely is found a greater height of the choir on the church

in Frankenberg indeed in combination with a widening thereof, but still in such a degree, that it also has a proportion of height exceeding that of the nave.

Meanwhile as stated, equality in heights of choir and middle aisle is the rule.

Galleries of hall churches.

With equal heights of the aisles there results for the narrower side aisles a far more important proportion in height than for the middle aisle, indeed twice when the ratio of width is 1 : 2. Therefore it is next to divide the height of the side aisles by intermediate vaults extending between their piers and walls, thus by the arrangement of the so-called galleries to enlarge the interior of the church, obtaining for the separate divisions in height of the side aisles a proportion in height quite or approximately harmonizing with that of the middle aisle.

Stone galleries.

Examples of such vaulted galleries are found to be especially common in the later works of the Rhine provinces, thus in the city churches at Kiderich and S. Goar, in S. Léonard in Frankfort and of S. Laurentius at Ahrweiler. The arrangement of the latter is shown in cross section in Fig. 890. Men originally regarded these galleries as separate aisles and furnished them with side altars, that are still preserved in Kiderich. On the other hand until recent years, there was found in the bay of S. side aisle precedeng the transept of the church at Wetter a gallery built later at the beginning of the 16 th century, which was originally intended to receive the organ and later was utilized as a so-called box for distinguished guilds. The design of this gallery thereby affords special interest, because its vaults are placed very low, cross and diagonla ribs are formed as rather flat segments, so that their mouldings intersect the round piers.

But likewise in many Early Gothic works with high middle aisles in France, on the collegiate church at Mantes, the cathedral of Noyon and that of Paris, are found such galleries on vaults above the side aisles, where the just mentioned separate position is especially accented, in that the width of the arch opening into the middle aisle is divided by little columns connected by arches. The vaults over these galleries in the cathedral of Paris show, that for later purposes, as we shall soon see, a

substantial peculiarity in raising the outer compartment from the keystone to the window wall.

Since the 16 th century have men believed that these galleries must be ever more common, at first in Protestant churches, but later in certain countries at least, also in Catholic churches, and they were devoted to a purpose essentially differing from the original one, when the separation from the other interior of the church and the establishment of separate altars therein was omitted. Then a view of the pulpit and altar in the rear row of seats was usually regarded as a necessity, and this must compel a raising of the floor toward the exterior like an amphitheatre.

It has been assumed as decided, that especially in restricted dimensions the effect of the interior is injured by these additions; if it is further true that the need for room is generally only imaginary, and as the requirement of a free view of the p pulpit only comes from a certain pious vanity; it is no less fixed that in many cases the disproportion betwiän the actual need of room and the means at hand compels this cheapest mode of obtaining room, or that at least the omission of the galleries and even only it is not carried out against the opposed wishes and opinions. It is yet more certain that Gothic architecture is more suited than any other to fulfil even an unfavorable programme.

Among the possible forms for the present purpose, one intimately interwoven with the entire mass of the building is most preferable, thus being the gallery inserted between the piers and outer walls. Therefore we attempt in Fig. 881 to carry this out with the least height, when we assume spans for the middle and side aisles of 7 m and 4 m in the clear and all projections, and place the base line of the former at the height of 5.5 m. As a minimum height of the crown of the cross arch of the gallery turned between the piers, we take 3 m and give this a rise of 0.75 m, assuming 4 m as the clear distance between the piers. If we now assume an inclination of 90 cm for the inclination of the floor of the gallery, the diagonal ribs of vaults forming the same receive a rise of 1.5 m, and the side arches at the o outer wall have one of 2.25 m. The entire clear height of 4.5 m thus results beneath at the wall.

With the assumed proportions of the plan, a semicircular form

of the diagonal ribs in the middle aisle require a height of a about 5 m. Accordingly we construct the vaults of the side aisles according to the data given on p. 371, so that the points of application of the thrusts are at the same height and accordingly their basis is about 75 cm above those of the middle aisle vaults. Therefore we place the capitals below the dividing arches and the ribs of the side aisles at the height of this basis, therefore higher than those of the middle aisle, so that as shown at c, they run against the cross ribs of the middle aisle. Thereby they will be raised as high as possible above the heads of persons on the gallery, and indeed in this case they lie about 2.5 m above the floor.

Wooden galleries.

If such galleries must be made of stone, a necessity which c certainly may appear in limited proportions by the lack of height and of means, the design of the woodwork must be such that the stonework of the piers will not be weakened by the inserted timbers. Therefore either those parts of the piers into which wooden posts or beams enter must have a changed form corresponding to this relatiin, or no connection of the two parts can occur. The first purpose would be attained by a corbel on the pier, which would afford the necessary bearing for the woodwork, so that the mass of the pier should not be weakened, but in a more perfect manner be stone segmental arches turned between the piers, on which the beams could lie. But contact could be avoided by placing separate posts at both sides of the piers. For the treatment of the woodwork and especially of the posts are given examples in Figs. 606 to 623.

3. Churches with Clearstory over Middle Aisle (Basilica) and their Buttress System.

Buttresses over single side aisles.

In hall churches with unequal heights of aisles (Fig. 888), we have the separation of the points of application of the thrusts and the resulting requirement of opposing sufficient resistance to the higher middle ailes. This necessity increases w with the difference in height of the points of application, and therefore most strongly appears with a height of the clearstory walls affording independent lighting of the middle aisle.

Importance of the clearstory of the middle aisle.

But in the adoption of the upper windows consists the particular

material reason for raising the middle aisle, just as in the l-
lack of this lighting is to be found a defect in the plan of a
aisles of equal height with great widths. This is plainly felt
by the view from the transverse aisle, or diagonally from a bay
of the side aisle, where the contrast of the dark shadows if the
vaults of the middle aisle with the full light of the vaults of
the side aisles produces a bad effect in even the most finished
works.

Moreover the impression produced by the whole is clearer; ev-
ery part has a proper value, so that the development of the el-
evation in a certain sense is furthered by the arrangement of
the design with side and transverse aisles, while that with eq-
ual heights of aisles, it is to be designated only as not oppo-
sing the latter. It is the proper church in all its internal
subdivision that is represented, while the different design with
aisles of equal heights approaches more the character of a hall
added to the choir.

But the peculiar triumph of the art lies in this, that it suc-
ceeded in forming a combination of the traditional basilican t
type with the advances in technics, and thus giving a justified
value to both principles.

In the flat covering of the basilica was offosed by none of
those technical difficulties, that were caused by the vaulting
and the need of abutments. If one now thinks that the requirem-
ent of vaulting was recognized, the suitable design for this
was found, at the same time the prescriptions of tradition were
removed, in other words radicalism was called to the execution
of the new designs. What would then be nearer than to abandon
the old types, to strive henceforth for a counter action of the
vaults also for church buildings, therefore directly passing to
the system of aisles of equal heigtt, for which use was in the
most varied directions found in the Romanesque churches of West-
phalia as well as in certain French provinces. But thereby was
not merely a phase of the development but the highest stage, w
which was even attained by the victory over the opposing difficulties

Instead of these the masters in the 12 th century sought one
means after another, and then ended by solving the problem of
combining the requirements of the present with the transmitted
form, creating a building and surpassed all precedents in depth
of constructive thought and in acuteness of expression, founding

a principle whose endless fertility also came to the aid of the different system. For without the material advantages of equal heights, certainly the prevailing system in Germany, recognizing the worth of so many examples thereof everywhere, it must be assumed that by those would not have been invented the richer development of detail forms, as first visible in Early Gothic works of this kind. For example how would men have come to the arrangement of the rounds, of the compound pier, if the organism of the construction had not required the separate different parts performing functions at different heights?

Purpose of the flying buttresses.

We have assumed above the independent lighting of the middle aisle as the impelling reason for the clearstory. But even with such a small height of the clearstory so formed as shown on the Liebfrauen church in Worms, there already appears, as illustrated in cross section in Fig. 891, the necessity of a separate resistance to the vaults of the middle aisle. This resistance can only be formed by a completely sufficient opposing mass, and it is therefore only necessary hn establish this mass so as to do no injury to the organism of the whole, as such would arise from an enlargement of the aisle piers, then to conduct the forces to be resisted to this mass. The first requirement would be expressed by enlarging the outside buttresses with regard to the increase occurring in the thrush, the second byflying buttresses turned against them, whilh are therefore first considered as struts.

Ensuring against bulging upward. Walls on them.

Accordingly the flying buttresses must have their crowns attached to the outer wall of the middle aisle at the height of the point of application of the thrust of the vault, but with its foot striking the inside of the buttress above the junction of the vaults of the side aisle. It is further necessary to secure the arch from an upward movement of the separate voussoirs, and this first occurs by the addition of a mass thereto as well as by increasing the radius. Accordingly there results in Fig. 891 only for this small height of the clearstory the possibility of the design shown there, whereby the flying buttresses are turned free in the space below the roof of the side aisle, without either supporting the purlins belonging to the roof construction or any extra wall. Moreover the entire design not appearing

externally has rather the character of an expedient certainly employed with advantage in certain cases than that of a real art form. There the considerable dimensions of the flying buttress 60 cm high and 90 cm wide are only necessary to ensure an unchangeable form of the arch line, but may suffer a considerable reduction, when the top of the arch is made an inclined straight line by masonry. This extra masonry may likewise either remain under the roof or better cut through it and be covered outside it by a slab with drip cut at both sides. By the last design would both the resistance to the thrust of the vault be effective at a greater height than would be the system expressed on the exterior. But to both arrangements corresponds in more complete measure that design, according to which the flying buttresses are turned above instead of beneath the roof, by which at the same time is entirely removed the restriction of the height of the clear story peculiar to the latter.

Counterthrust of the arch.

We have then the flying buttress as merely conducting the thrust to the nearest buttress, hence being in a sense regarded as a neutral body like a wooden shore. But in reality the case is different, so far as by its properties as an arch it exerts an active thrust at the junction with the wall of the middle aisle, by which a part of the thrust of the vault is neutralized. The intensity of this force is dependent on the weight and curvature of the arch as well as its loading, but the direction of the force on the direction of its junction with the wall, hence on the location of its middle point (Figs. 402 to 405). The effect of this force would therefore be the greatest against the thrust of the vault, if the flying buttress were made the heaviest possible and were turned in a flat arch, that joined the wall horizontally or somewhat inclined. If the arch is more curved ((for example as a quadrant) and is less loaded, its thrust is less. Thus one is able within wide limits by weight, curvature, and rise of the arch so to determine its end forces in magnitude and direction, as it favors conditions of stability. (Figs. 408, 409, 410). Thereby the thrust of the arch can be made less or greater than the thrust of the vault.

If flying buttresses are employed that much exceed their duty,

the two walls tend to move toward each other, and consequently to firmly hold the vaults. Cross vaults can bear such an increased transverse stress by the frequently mentioned stiffness of their compartments or cross arches, within fixed limits without injury (p. 168, 339). Thus too heavy buttresses are less unfavorable to the vaults with correct height of attachment, and even by "correctly" stiffened cross arches they may preferably increase the immobility of the entire work, but they have another fault as a consequence. For the equal thrust that the arch above exerts against the wall also occurs at the lower end, wherefore an excessively heavy flying buttress also requires a particularly strong buttress, and this must be obtained by a greater quantity of materials. It follows from this, that as a rule a rather light construction of the arch must be preferable. Therefore it is the first concern to reduce the cross section of the arch as much as the ratio of the strength reacting through the buttress to the transmitted pressure permits. But these pressures could change by variation in wind and loads, as mentioned before (p. 130), or in other words there may occur in the flying buttress sometimes flatter and more curved lines of support. To be able to receive these at all times without breaking, the means nearest at hand is a stiffening wall on the arch. But since by this a load increasing with the inclination of the upper edge is laid on the flying buttress, as a rule at least for any considerabele inclination to open that wall by a great circle sometimes beset with cusps (a in Fig. 892).

Form of the arch line.

With the quadrant form of the flying buttress its thrust is about horizontal against the clearstory wall, and this the horizontal component of this thrust is directly opposed to an overturning of this wall, so that the vertical component remains in full force, loading the aisle pier and the weaker construction above. But just in relation to the latter is advisable a reduction of the loading, and thus it is preferable to shape the flying buttress so that its thrust strikes the wall in an inclined direction, thus neutralizing a part of this force acting vertically. But this inclined direction results from the adoption of a greater radius for the flying buttress, thus locating the centre in the inner face of the wall, as at c in Fig. 891, or far-

farther inward, and thereby the flying buttress receives a height exceeding that of the quadrant. If this height does not exist in the general proportions of the cross section, then the intersection of the flying buttress into the roof of the side aisle, or lowering it to the springing of the cross arch of the side aisle will be necessary. At the Regensburg cathedral a lesser height of the flying buttress is obtained by striking it f from three centres.

Passages in the clearstory wall below the arch.

Below the attachment of the flying buttress and with a full neutralization of the thrust (Fig. 409), for the clearstory wall or rather for the pier formed by it is only a thickness required by the condition of the reacting strength of the stone opposed to the loading reduced by the flying buttress. Hence results the possibility of replacing the pier mentioned by two supports, b between which is spared the space needed for the passage (b in Fig. 892), thus constructing a passage to make the windows of the clearstory accessible, as already represented in Fig. 857. In works in Burgundy, in the cathedral of Toul (Fig. 850), and Freiberg cathedral (Fig. 892) the passage lies inside and the window wall is placed at the outside face of the wall, the flying buttress either direltoy serving this as in Fig. 891, or there is set against one of the lower aisle piers, either a corbelled buttress as in Fig. 895, or finally as in Fig. 892 against a mere projection. But in the interior this arrangement occupies space, that was priviously explained in the galleries of single-aisled churches. Accordingly Fig. 892 shows the arrangement of tunnel vaults in the thickness of the wall, and Fig. 892 a is the plan of this Fig. at the height of this passage, that for a row of windows filling the entire length of the bay would receive a form about corresponding to Fig. 855 a.

On the same structural principle is based the design of external passages. There the window wall alternates places with that internal pier a b c d in Fig. 892 a, and thus is set back to the inner face of the wall. According to the width of the window the jambs come to lie against the rounds of the side arch, while the tunnel vaults in the thickness of the wall appear externally as on the cathedral of Rheims (Fig. 894). We note here that overhanging form of cross section of this tunnel vault is

not fanciful, but first develops at the jamb from the proportion of the rounds of the pier in the angle at the transverse aisle to the thickness of the wall (894 a), where alone by the adoption of the splay also extending on the arches and before the o other bays results the possibility of the plan of the pier a.

Isolated columns beneath the flying buttress.

Yet where the thickness which the wall resting on the window arches receives by that tunnel vault exceeds the necessity of the necessary stiffness (p. 338) requires in the upper thickness of the wall required by gutters and galleries as well as the roof beams can easily be obtained by the form of the cornice a and by internal corbellings, since the tunnel vaults or rather the arches connecting the piers outside the window wall disappear, and there remains only the pier itself in the thickness of the flying buttress or of a little greater thickness. The flying buttresses are then turned against these piers and are furnished with passages beneath their junctions, while they terminate above either in the flying buttress, or continuing through these have a separate ending. Viollet-le-Duc, Vol. I, p. 63. But it fulfils the purpose to be satisfied, if the thickness of the outer pier formed at the junction of the flying buttress is retained, i.e., the buttress also above the height required by the passage can also be replaced by an isolated column, whose capital stands beneath the ashlar receiving the front end of t the flying buttress, while its read end is inserted in the wall and finds further support by a wall pier projecting from its face. An example of this kind is shown by the buttress system of the Strasburg minster (Fig. 893). Here a is the ashlar met by the crown of the flying buttress arch and supported by the column b, c is the pilaster, whose width exceeds the thickness of the flying buttress as represented in the plan of Fig. 893 a, so that this excess at both sides of the flying buttress enters below the cornice.

By the steeper direction of the top of the flying buttress, the height is increased at which the resistance of the thrust of the vault becomes sufficiently effective in moderate dimensions, by which however the measure of the loading may be reduced by means of the before mentioned openings. If we now assume a complete perforation of the triangle between the flying buttress arch and the straight portion, as by filling it with tra-

tracery or mullion construction, whose strength suffices ho bear the cut stones of the covering (Fig. 899), then the resistance of the height between arch and coping would be lost, and besides the arch itself the straight top or coping would form a second shoring of the wall, but sufficient security is obtained thereby, since even if a part of the thrust acts between the two secured points in Fig. 899, yet their distance apart is too small for a bulging of the wall to result.

Two flying buttresses ofer each other.

But the safety obtained by the top and sidewise stiffening is in inverse proportion to its inclination, and the resistance is almost entirely lost, if it is steeper than the thrust of the vault. But that doubled stiffening is obtained in a more complete manner, and at the same time the height of the line thereby ensured increases as desired by the arrangement of double flying buttresses over each other. The lower flying buttress reaches the clearstory wall about the thickness of the pier above the height of the capital, and the upper one about 2/3 to 3/4 of t the height of the vault, to the latter entirely falls the task to resist the wind forces applied above, etc. The direction of the top will be less steep and according ar a rule the perforations must be omitted.

The junction of the upper flying buttress on greater works, as at the cathedrals of Cologne, Amiens and Beauvais, then occurs in entirely the same manner as that of the lower on the block supported by a column, so that the upper column stands exactly over the lower one. But since the purpose of the passage under the upper flying buttress vanishes, there is sometimes found(as on the cathedral of Chalons, Fig. 898), that isolated column is replaced by an external buttress, to which the column receiving the flying buttress is attached as a round. This upper buttress then rests on the lower block and its front face remains behind that of the lower column. Each external buttress at the same time affords a very useful strengthening against the inward forme of the upper flying buttress, which strikes the wall at a place where the proper thrust of the vault is but indirectly effective. Still greater security against that force pressing inward results from the erection of transverse walls on the cross arches, and made horizontal at top, as at the cathedral of Rheims, which then to avoid the excessive

loading of the spandrel of the arch may be opened by circles in the angles.

Certain works like the cathedral of Bourges even show three flying buttresses over each other, which can then meet more safely any variations in thrusts by their strength and points of application. Yet such a large number of arches are unnecessary, they must also owe their existence only to the circumstance, t that at first the master had ont clearly considered the effect of the forces. Likewise the omission of the second upper arch must have resulted from the observation, that a deep arch with a short base stiffened the upper part of the wall too little, which must appear after the first storms shook the building.

A peculiar form of construction recalling the system of the doubled flying buttress, but based on an entirely different principle, is shown by the flying buttresses of the cathedral of Chartres. Here the lower or rather the actual flying buttresses are covered by a concentric arch forming a drip at each side, on which stand little radiating columns connected by round arches. On the end arches brought to a coneentric line with the flying buttress lies a low layer of larger blocks and on the latter is one concentric with the lower and corresponding in thickness as an arch, built above to an inclined straight line with a coping moulded at each side. Thus not including the low covering layer and the arches separating the upper arch, and transferring the entire load to the lower one, there are two flying buttresses, the upper usually for receiving the thrust, while they strengthen the lower, so that the upper arch no longer forms a passive stiffening, as a straight inclined coping course would form in like manner.

This double arch at Chartres has been too little considered in its refinements, and like those copings supported by openings (Figs.897, 899) affords undeniable proofs, that the old masters with great acuteness recognized the importance of upper arches and of the stiff coping over single arches as sometimes acting as stiffening against variations of wind, and in a model developed their construction and architectural expression.

Loading of the top of the arch.

But all loading of the lower arch also prevents the yielding of its ashlars and so ensures its curvature.

Such security by loading is effected in various ways; thus on

the cathedral of Cologne by tracery placed on the back of the flying buttress, on other works by separate mullions and arches supporting the coping and water channle, that will pe mentioned later.

Contrary curve of the coping.

In far simpler manner the permanence of the curve is ensured by the form of the straight coping or rather that of the flat arch with the contrary direction as on S. Benigne at Dijon (Fig. 895). Accordingly the two opposed arches ensure each other, and both extend in the same way between the buttresses and the wall of the clearstory. But the effect of the form of the upper curve is unpleasing in this example, that is to be referred to the fact, that the curve bends at the flying buttress in a steeper direction.

The arrangement of flying buttresses over doubled side aisles.

Arches of single and double spans.

We have already stated on p. 289, that these may occur by two different principles, according as either the flying buttresses extend as one over both aisles with a radius exceeding their width, as on the cathedral of Paris and the minster at Ulm, or are turned in the ordinary way in two spans. In the latter case are placed piers over those separating the aisles, which pass through the roofs of the side aisles and are joined by the lower flying buttresses, and also the upper rest on them. The lower flying buttresses must then transfer to the external buttresses the thrust led to the intermediate piers by the upper ones, so that the intermediate pier requires no great dimensions, certainly under the effect of a loading acting vertically.

Junction with intermediate pier.

The simplest relation of both arches to each other will then be, that they are entirely equal, or receive corresponding forms with unequal width of side aisles, and that the backs of the l lower continue the direction of the upper arches. Then accordingly as shown in Fig. 896 the thrust of the latter strikes at about a the line leaving the intermediate pier, it is opposed here not by the thrust of the lower arch, bat by the wall on it and conducts to to the external buttress. But the thrust of the lower arch strikes the intermediate pier at b and also is opposed by no direct force. If this on account of the small intensity

of the force acting at B from that striking at a above, and further on account of the small distance between the points of application in actural danger results therefrom, then is still t the arrangement given in Fig. 896 a the more consistent, when as on the choir of S. Ouen in Rouen, the junction of the lower flying buttress with the intermediate pier is placed somewhat higher, so that its thrust directly opposes that of the upper, and accordingly the continuity of the direction of the backs d disappears.

Double arches over double side aisles.

If the design of doubled flying buttresses over each other came from the desire to stiffen the entire top of the wall exposed to the different thrusts by securing its ends, the same principle may also find application in the converse sense, in the way that the thrust brought to the intermediate pier by two upper shores is opposed by only a lower one. A simple example of this sort is the buttress system of S. Peter Jr. in Strasburg. (Fig. 897). For here on the back of beal flying buttresses are set posts, that bear ashlars set in an inclined line. These last a also become a second shore just like the preceding wooden strut, so that the thrust of the vault of the middle aisle is led to the intermediate pier at two points over each other, and only the single lower flying buttress opposes by its entire mass those double points of application, and strikes between them, leading to the external buttress. More decidedly is expressed this view if two upper flying buttresses are opposed to a lower one. Such an arrangement is found in the original buttress system of Notre Dame in Paris, where the lower flying buttress of the second span opposes the thrust of the gallery vault and of that concealed beneath the roof of the latter and the flying buttress supporting it, and acting at different heights of the same intermediate pier.

Double stresses from flying buttresses are found on the choir aisles of certain French cathedrals, required by the plan of the pier separating the chapels, so that the outer flying buttress receives much less stress and therefore its active effect nearly vanishes. Hence at Amiens this stress is entirely neglected and the last flying buttresses are conceived as only conductors of the thrust to the outer pier, therefore being replaced by a complete pointed arch.

Arrangement of removal of water by buttress system.

Channels of gargoyles.

The earliest arrangement of channels and spouts undertaken s still in the 13 th century on the cathedral of Rheims, differs nowise from that already explained. By the latter the water coming from the roof of the middle aisle was thrown from the channel into the air, where it was scattered by the least wind and thus falls on the roof of the side aisle without causing too much injury in its scattered condition. If the spouts are now found directly over the flying buttresses, the origin of this may rather be found in a formal need than in the intention to utilize the backs of the flying buttresses to break up the stream of water, which could not be done with the least wind.

But there is in this a not too distant contradiction, that the water flowing down from one roof is first collected in channels, this is scattered in the air and falls on a second roof, at whose base is repeated the collection. Then there is either a step back or one forward to be taken, i.e., either to omit the collection of the water in the gutter of the roof of the middle aisle, or to remove the water collected theron in separate channels to spouts and removing it entirely from the building. The first arrangement is that usual on Romanesque works, and which still frequently occurs in the Gothic period, on Notre Dame at Dijon among others. There are indeed also lacking t the lower channels, yet their addition would be an improvement very well combined with the free flow from the upper roof, and would be thereby justified, that the water from the lower roof falls on the horizontal surface of the roof, and therefore would be more easily carried to the walls, even if not thrown to a g greater distance from them, as by the gargoyles.

Channels on the backs of the arches.

As for the second arrangement, the backs of the flying buttresses are very well suited for the arrangement of the special channel, and there is first concerned the carrying of the cross section of the latter from the outline of the gable into that of the gutter, and then the channel thus formed to reach the stream from the gutter of the roof of the middle aisle. Satisfying the last condition will be more difficult as the distance from the junction of the flying buttress to the roof gutter increases, as it particularly occurs with single flying buttresses,

where the necessity of a vertical pipe is found.

On Strasburg minster, as Figs. 893 to 893 b show, wall piers project from the clearstory walls of the middle aisle, that are joined by the flying buttresses, and which above this junction are strengthened by little columns standing on the backs of the flying buttresses. Then the capitals of the latter, as shown by Fig. 893, are taken from the height of the roof balustrade and bear the finials rising above the latter. Within the projections thus formed is found to be cut a vertical pipe, as shown by the plan in Fig. 893 b, through which the water from the roof gutter is led to the gargoyle, which casts it into the channel formed on the back of the flying buttress. Therefore the water pipe lies before all not in the wall, and can also be made safe by a lead lining. Fig. 893 e shows the section of the arrangement.

Entirely similar is made the conduit at Freiburg. As shown by Fig. 892, the wall of the middle aisle is formed of five sides of an octagon, and wall piers stand on the backs of the flying buttresses, furnished below the roof gutter with strongly projecting capitals, so that the area obtained becomes a basin likewise enclosed by the balustrade of the roof, from which the water flows down through the pipe enclosed by the wall pier, and is led to the enclosed pipe forming the back of the flying buttress. Fig. 892 b shows the section of the latter.

The essential difference of this plan from the former consists thus in the more complete enclosure, in the substitution of the enclosed pipe for the open channle. Any advantage can be less found in it, since thereby the removal of any stoppage er made difficult.

From the arrangement mentioned above differs that of the cathedral of Seez seen in Viollet-le-Duc, in that the pier enclosing the pipe instead of standing on the back of the flying buttress, is corbelled out about the height of a course above its junction with the wall, and this corbel is formed by a great lion's head with open jaws directed downward, thus openly casting the water into the channel.

If then in adopting an open conduit is found one advantage, this is even increased by the omission of the front wall of the pipe leading the water down from the gutter, whereby it in a sense takes the form of a vertical channel.

Moreover if an advantage is to be found in the adoption of an

open conduit, this will be even increased by the omission of t the front wall of the pipe leading down from the gutter, whereby this in a way assumes the form of an open channel. Such an example is offered by the cathedral in Regensburg. For here that p projecting pier in which the pipe leads town in the before mentioned examples is replaced by a triangular case open on two s sides, so that two of the same adjoining little columns are next the wall and the third stands free, and the entire form stands on the back of a gargoyle, that casts the water into a channel on the back of a flying buttress. An improvement of this arrangement would be its connection with the peculiar spout at Seez, so that also the point where the vertically falling water must change to the oblique direction is opened.

The opening of two sider of the triangle brings with it the fault, that the water falling inside it may be driven by the wind and be scattered over the roof of the side aisle, without reaching the channel on the flying buttress. By a rectangular form of the conduit with closed side walls this fault could be met, but still better if the duct passes from a vertical to an inclined position, in other words, that the channels on the backs of the flying buttresses are made steeper just before they start at the wall of the middle aisle, then extending close under the proper gutters of the wall of the middle aisle. Such an example is found on the choir of the cathedral of Auxerre. (Perspective view is represented in Fig. 899).

The arrangement mentioned is there connected with another that has substantially the same purpose and is executed in the most varied forms on many mediaeval works. We mean an elevation of a special water conduit resting on the latter. There the ashlars forming the channel are supported like the handrail of a stair balustrade, either by a system of vertical muntins connected by a straight lintel or by arches od various forms, as on the choirs of Amiens and of Auxerre (Fig. 899), or by a balustrade placed at an angle to the direction of the channel, as on the cathedral at Cologne. A simpler form of this kind is formed by the upper flying buttresses of S. Peter Jr in Strasburg. With the arrangement of a series of muntins must the proper flying buttress be covered by a concentric course or by one parallel to the inclined direction of the channel (Fig. 897), on which are then wrought the seats for the muntins. Now that the ashlars

of this course are made so large that each of them supports at least one muntin, each voussoir od the arch receiveu its load and this will ensure it against any rising upward. That in many, even if not in all cases, the upper covering had to serve as a stiffening as well as to carry water as mentioned elsewhere.

Further description of flying buttresses and details.

Line of the arch.

As for what concerns the line of the arch itself, we have already mentioned above the greater advantages of a greater radius, and therefore the adoption of a centre inside the inner face of the wall. After fixing the centre the radius is directly found by the distance of it from the inner face of the buttress, or from the round here given and supporting the flying buttress, which can stand about over the round of the cross rib of the side aisle. Accordingly the line of the arch is vertical at its beginning. Hence the line of the arch corresponds to half a pointed arch and is itself very steep, so that its force at the upper end is directed more or less obliquely upward (Fig. 405); if it is low and thus less than a semicircle in height, its upper force will be quite or approximately horizontal (Figs. 402, 404). The steeper the arch the less will be its horizontal pressure with the same weight, and so muct lower will it be carried down to the buttress. Moreover steep arches can serve to receive a part of the vertical load of the clearstory wall.

But a limit of the height of the arch may seem required by t the general conditions, and will result in lowering the centre and increasing the radius, so that accordingly the flying buttress only appears as a segment of a half pointed arch. Thereby will the proportion of the thrust be so far influenced, that the thrust of the arch falls higher at the junction with the buttress, and is increased with the weight of the arch otherwise remaining the same.

Cross section of the arch.

The conditions on which depend the necessary dimensions of t the flying buttress depends we have already examined above and in regard to what was already stated, there, will be compared h here with each other only two different works. For on the Freiburg minster, where permanence of the arch line is ensured by masonry laid thereon, the depth of the arch amounts to 45 cm

with a thickness of 40 cm, and a span of 8 m, while on the not covered flying buttresses of the Liebfrauen church at Worms is found a depth of 60 cm and thickness of 90 cm for a span of about 4.5 m.

On the earlier works the cross section of the flying buttress is either square or with chamfered angles. Richer sections are shown by those of S. Ouen in Rouen (Fig. 900), and still more ornamental are those of the cathedral of Cologne and of the church of S. Katherine in Oppenheim (Fig. 901 b). A construction with two courses lying on each other like dividing arches is just as superfluous, for the function of the flying buttress as unsuitable to the smaller thickness. On the contrary are found on certain later works added suspended simple or compound arches attached to the lower surface, after the analogy of window tracery.

Besides the economy of the earlier mode of treatment a freer distinction of a sharper characterization is peculiar to them, in so far as they save the richer members for the interiors, for the arches under which men pass, but omit them on flying buttresses turned above the roofs. Therefore such refined members contrast in but limited measure with the mighty swing of the line of the arch and with the great dimensios of adjacent parts of the building.

Coping.

Over the backs of the flying buttresses is a moulded coping, if it comprises no channel, to what is later said on the forms of gables applies, but with the difference that on acconnt of the lesser inclination, the horizontal joints must be exchanged for those perpendicular to the inclination.

Enclosed pipe.

The form is little or not at all changed by placing an enclosed pipe in the coping, as found on Freiburg minster and the c church of S. Katherine in Oppenheim. On the church last mentioned indeed is only visible the intention of such an arrangement by the ashlar a of the external buttress represented in Fig. 901, which should be adjoined by the coping of the flying buttress. Fig. 901 a shows the same in front. On the end piece of this coping b built in the clearstory wall of the middle aisle in Fig. 901 is on the contrary found an open channel, which indeed contradicts the assumed arrangement on the buttress, so that either an alteration of the originally intended arrangement

or the subsequently intended addition of the upper half of the pipe is to be assumed. Fig. 891 b then shows the profile of the enclosed pipe found on the backs of the Freiburg flying buttresses, consisting of two courses. A similar arrangement occurs on S. Barbara at Kuttenberg.

Moreover the plan of the enclosed pipe in this place is chiefly to be rejected, though this in Freiburg still dates from the Early Gothic period, and also seems to have caused no faults in the course of time.

Open channels.

The advantages of such open channels on the flying buttresses consist in the ease by which any accidental obstruction to the removac of the water can be removed, and the need of drying out. Since access to these above the roofs of the side aisle yet remains difficult, then the balance again inclines somewhat in favor of the closed design, by which all stoppage is avoided, if the drying is not also essentially hindered.

The simplest form of an open channel is that in Fig. 893 d. Richer members of it are found on Strasburg minster (Fig. 893 b) and the cathedral at Auxerre (Fig. 899). It must be combined w with an open channel and unite above in a single form of leaf or bud (Fig. 902), or the leaves must be visible at both sides, their thicker parts growing together above the opening. Such forms are found on the cathedrals of Cologne and of Regensburg. On the contrary on French cathedrals the crockets are usually lacking in these cases, indeed even when with double flying buttresses they crown the backs of the lower and enclose no channels.

Junction with the middle aisle.

The junction of the flying buttress with the clearstory of the middle aisle occurs as stated above, either directly or on a buttress carried from the ground or one supported by little columns, whose width usually agrees with that of the flying buttress, thus first on the block of the wall laid on that column, so that the last radial joint of the arch lies outside the supporting impost (a in Fig. 893). That this block must have a considerable depth or be strengthened by ashlars lying on it results from the load of the wall thereon. As a rule it then r remains simply rectangular, so that the members of the flying buttress stop against it, or by a bend extend down vertically

to the capital of the column, yet it may assume a recher treatment. Thus in Amiens blind arches rest on the capital of the column and are wrought in the side surfaces, whereby results o one of the most varied motives capable of execution, while in Cologne the complete system of gables and finials are carried out on it, so that as represented by Figs. 903 and 903 a, the members of the flying buttresses extend down between the angle column and the capital of the column, but at the same time cover the passage by arches cut through the lintel.

The junction of the coping of the back occurs in the same manner, so that the beginning of the members concerned are wrought on a bonded ashlar as shown at b in Fig. 901. With the arrangement of a channel, either its beginning is made in one piece with the spout or gargoyle as in Strasburg (e in Feg. 893), or there must be entire separation as given by the design at Seez explained on p. 392, or at least the gargoyle rests on a pedestal, through which the joint can pass.

The entire mass of the part of the wall resting on the block, against whose front is turned the flying buttress, then forms an opposing masonry adjoining the wall of the middle aisle, and may either terminate under the coping of the flying buttress, or serve as a base for the most varied forms of piers and finials strengthening the balustrade of the roof. Thus either piers may be set on which above the returned roof cornice of which t the pinnacles stand, or the latter directly so that only colossal figures stand at the balustrade of the roof, or giants without bodies rest on the flying buttress, or finally the pinnacles first stand on the roof balustrade as in Strasburg (Fig. 893),. A very beautiful solution is found on the choir of the collegiate church at S. Quentin, where the copings are unrolled at the junction with the wall of the middle aisle, and figures stand on the volutes thus formed, which rest at the face of the wall.

Moreover how buttress walls become analogous to the actual buttress piers, then window arches, gables etc., find their connection as on the latter (Fig. 901).

In regard to the junction of the arch with the clearstory wall, Viollet-le-Duc (Dict. I, p. 64) indicates there that it is important to be bonder above but th form vertical separating joints, in order theprevent the possibility of slipping, a rupture of the arch by different settlements of the body of the wall. He

asserts that a failure of this free jointing almost always systematically results.

It is to be noted here, that a slip in a stressed arch is to be termed improbable, and that on the other hand the opened joint in movements and especially in variations of wind may prove favorable in a different sense. If in Fig. 904 the usual line of pressure is denoted by I, it will be transferred by wind from the left like II, and on the contrary a wind from the right will form the straighter line III. Thus in some cases the pressure may be moved so far toward the upper or lower edge, that a temporary opening of a joint may occur at the opposite side. If a through joint exists, this may open somewhat without hindrance; if it does not exist, then on the contrary with firmly bonded ashlars a rupture may occur at the points A or B, or if the strength of the materials resists this, a fixed end being assumed, a break of the arch at C.

The procedure is more clearly intelligible, if it be considered not statically but dynamically as represented in the sketches of Fig. 904 a, b and c. Fig 904 a shows the joint opened above by a wind from the left, Fig. 904 b on the contrary below by o one from the right, and Fig. 904 c exhibits the breaking of the arch at its weakest place if dixed at the top.

Proportions of heights of the basilica.

This is in a certain relation to the previously developed structural system, if already the limits derived thereby are very wide. For example if the width of the side aisle = 1, that of the middle aisle = 2, the height of the side aisle =2, that of the triforium = 1, so that the roof has the direction of about 45° and the height of the clearstory = 2, there results for the middle aisle the proportion 2 : 5, that is already to be regarded as a maximum ration, whereby the window sills lie far below the capitals of the rounds, so that in ordinary cases a reduction is required. Such would first affect the height of the window story or light story according to the earlier and better expression. If the window occupies the entire length of the bay between the rounds, as a limit to it may be regarded a raising of the window sill to the capitals of the rounds, whereby the height of the clearstory required by the height of the vaults amounts to about 1 1/4. If we also reduce the height of the triforium to 3/4, then will the height of the middle aisle

correspond to that of the side aisles and be 1 : 2, and can be still reduced by lessening the heights of the side aisles.

Even smaller heights can result frsm smaller widths of windows, for which we can mention the church at Rheims as an example (Fig. 921), where the capitals of the triforium columns lie at the height of the capitals of the rounds, so that the sill of the windows of about 2/3 the length of the bay is moved up to the base of the side arch, and gives a proportion of 2 : 3 for the middle aisle.

Form of the buttress receiving the flying buttress.

The abutments of the flying buttresses form the additions to the walls of the side aisle for the adjacent buttresses, and therefore as a rule are set with their inner surfaces beyond the inside face of the wall, or if the rounds standing there in the side aisle have sufficient size, beyond the inner side of the latter. But since the width of the round is mostly far less than that of the buttress, as a rule there is over it a narrower part of the pier or again a round, which affords the bearing for the flying buttress. However this projection is also usually wanting, and the flying buttress rests on a corbel that projects frsm the inside of the pier, or it starts directly from the latter. Not rarely the upper bearing is corbelled out inward considerably beyond the inside face of the wall or its projection, to more effectually oppose the thrust of the arch.

Conducting the water from the side aisle.

The entire projection in the simplest case continues in play with the lower part of the buttress. In richer designs the cornice of the roof of the side aisle is broken around it, and over this is usually found a projection. Yet where the passages on the roof cornice require openings through the buttress, these projections can only be small or be only placed over the passage. The floor of the opening forms a continuation of the gutter. T The water cay either flow out through a channel extending through the width of the pier and a gargoyle or two set diagonally, or they can be set in the angle between the buttress and the side wall diagonally, or a channel for the water can be carried around the upper part of the buttress, and accordingly the opening through the buttress be omitted, if that channel has sufficient width to make it accessible.

Such an arrangement where the entire length with the balustrade

before the front part of the upper division on the height of t the buttress, that is adjacent to the upper flying buttress, a are set four little columns forming a square and connected by three blind arches, which stand on a projection of the lower part of the pier and form the basis for the pinnacle placed above them. By such an always simple design is obtained a closer connection of the finial with the flying buttress, the decorative effect is enhanced at the same time by the reproduction of the dimensions of the lower pier in the pinnacle, and in a certain sense is expressed the sthuctural idea, that results frequently later in extensively overrich and extremely varied solutions, or appears even less clearly.

However when the system of terminating in a finial had found a complete development, there appeared the endeavor to employ it in the oblong form of that addition, chiefly that of the entire pier and in a more artistic manner. The simple roof of the buttress entirely disappears, and also the surfaces remaining beside or before the terminal pinnacle were divided into finials in the most diverse ways.

Intermediate piers with arches of doubled spans.

For systems of buttresses with double spans, thus over 5-aisled plans, piers stand also above the intermediate piers of the side aisles, which cannot act as proper buttresses, on which rest the upper buttresses and the lower ones adjoin. In the simplest cases these may receive the form of the ordinary vault p pier or of stronger columns. Meanwhile it is also very near to aid the stability by loading, i.e., to give those piers an independent termination rising above the junctions of the flying buttresses, instead of leaving them beneath the coping of the flying buttresses. By the plan of the aisle piers as well as by their function, these intermediate piers will rather take a concentric plan in contrast to the oblong one prescribed for the external buttress, thus the shape of a polygon or of a Greek c cross as in Cologne, whose four wings end in pinnacles, which giants grow up around the terminal pinnacle standing on the central square. This form of motive in Cologne is then extended also to the outside buttress, only being changed in the latter in accordance with its function so that the outer arm of the cross is considerably extended, on the front side of which is placed a separate terminal pinnacle, or rather is projected so

or front face of the buttress or over the middle of its depth. The first arrangement is indeed to be regarded as most preferable in statical respects, since it moves the centre of gravity of the entire mass of the pier nearer the interior, and therefore increases the lever arm of the resistance. Thus is it found on the Freiburg minster (Fig. 894). But on the other hand the otherwise sufficiently heavy projection brings the placing of a lighter pinnacle over the front face, as found on many French works, producing for the standpoint of the observer the effect of great firmness, certainly making more apparent the principle of loading. Besides the actual loss in statical effect is only very small.

Placing the pinnacle over the middle of the depth of the buttress is found most simply on the cathedral of Chalons (Fig. 898) , in richer form on that of Beauvais. The pinnacle of the last work, with a body consisting of four little corner columns connected by arches thus forming a shrine, which however does not contain a figure as usual, but covers the great pinnacle p placed between the roof of the buttress between those columns, is an arrangement which is then transferred to the original form of the buttresses of Cologne cathedral,(Note), and produces even by the expression of the greatest richness a peculiarly astonishing effect. Yet we might give the preference to that older arrangement, where the terminal pinnacle has an unsymmetrical position. Indeed the entire buttress thereby has a less independent form, but its belonging to the whole is clearly expressed.

Note. Changed at the restoration. See Reichensperger's Miscellaneous Essays.p. 320.

On the buttresses of Strasburg minster, that addition consists of a lower sloping mass, that moves back the centre of gravity, above this being a pier of oblong plan, whose front portion forms a pinnacle (Figs. 893, 893 e). Thus the little corner columns of the pinnacle stand flush with the mass of the pier with bases on the projection of the cornice, so that also in the arches and gables of the pinnacle is a projection and the gaple roof of that part of the pier terminates under the gable of the pinnacle. The strasburg termination must be temmed particularly happy, since it combines a good position of the centre of gravity with a clear architectural effect. An allied arrangement is found on the old buttresses of the cathedral of Amiens, where

is broken around the buttress, and which occurs on the choir of the cathedral of Clermont, but also on the towers of Strasburg and of Colmar, leads to an offset also in the thickness of the buttress, whereby only the unusual width of the lower part of the pier is obtained a sufficient area. With ordinary dimensions corbels in the thickness of the pier are necessary, that may either extend on the front side or be replaced there by the possibility of a sufficient offset, but in any case may lead to the richest and most varied forms. If then over the different bays of the side aisle are arranged separate gable roofs, the water from the gutters between them can be carried around the buttress.

Upper termination of the buttress.

What now concerns the upper ending of the buttress, the simplest design of this is a gable roof lengthwise, against the rear gable of which starts the coping of the flying buttress and thereby determines the height. Such buttresses are found on the c churches of Pforta and of Mantes (Fig. 905). The height of the ending can be further reduced by continuing the back of the flying buttress to the front gable, whereby the extra width required for the buttress resistang by its weight the turned arch, and that is already necessary by the condition of resistance, joins the buttress at each side with a wash. Likewise here very different forms are possible.(Figs. 906, 907).

Then if a channel is found on the back of the flying buttress, the gargoyle may either lie horizontally on the roof op the pier (Fig. 908), or on the top of the pier may be formed a basin, f from which the water flows through a spout placed lower (Fig. 909), or finally the water may pass downward through the roof of the buttress. There substantially applies in all different designs about what is said on p. 362 et seq. Yet we note that the design of the spout on the buttress like Fig. 908 requires very long stones, and therefore a deeper location ensured by the loading results in a substantial reduction in weight.

Added pinnacles.

An increase in the resisting force of the buttress by a greater loading leads in the simplest form to raising the roof of the pier above the junction of the coping of the flying buttress (Fig. 912), but in richer shapes to a horizontal projection or one consisting of several gables above it, or to a great or a complete pinnacle. This additionthen either stands over the back

but the middle vaults have masonry on the cross arches, which in common with the flying buttresses form a strong cross stiffening. One cu. m. of tolerably heavy machine made bricks may weigh 1800 kil. The remainder results from the section in Fig. 912.

It will first be computed how great must be the counter thrust of the flying buttress placed at the height of 18 m with the assumption, that the pressure goes down at the centre of the bottom end of the middle pier.

For the latter point will be established the equation of moments for all forces, that act on the middle pier above the ground with the wall loading it. The forces are the following.

The sought horizontal thrust B of the flying buttress that t turns to the right with a lever arm of 18 m, the thrust of the side vault H_2 = 2160 (p. 154) likewise turns right, and acts in round numbers at 8 m above the floor. The vertical pressure of the half side vault V_2 = 6940, that acts at the side of the dividing arch, thus about 0.39 m left of the moment pivot. The left turning thrust of the middle vault H_1 = 3240 (p. 154), and passes into the face of the wall about 17.5 m above the floor. The vertical pressure of the half middle vault V_1 = 10,260 with a lever arm of 0.39 m and turning right. To these are added the horizontal and the verticalresistance of the masonry on the cross arch. The latter acts with a lever arm of 0.39 m turning right and equals half the weight of this masonry, which with 25 cm thickness and 7 sq. m vertical area amounts to V g = 7 × 0.25 × 1800 = 3150 kil. The horizontal thrust of the cross arch with this masonry turns left and varies with the wind, etc., in favorable conditions it can act at the same height as the thrust of the vault, thus 17.5 m above the floor and turns left, then amounting to about a third of the vertical force Vg, so that Hg = 1000. The weight of the pier with the clearstory wall resting thereon amounts to about 110,000 kil after deduction of the windows, recesses, etc., and is omitted in the calculation, since its centre of gravity falls over the middle of the pier and thus has a lever arm = 0.

According to all this the equation of moments of the forces turning right and left is :--

$B \times 18 + H_2 \times 8 + V_1 \times 0.39 + Vg \times 0.39 = V_2 \times 0.39 + H_1 \times 17.5 + Hg \times 17.5.$

adjacent parts of the pier must not become entire regularity, rather as there always a certain relation of them to each other to be preferred. Thus on the piers of Rheims the coping of the flying buttress joins the gable roof of the pier, and the latter terminates above the capitals on the shrine with the figure, so that the ridge of the roof ends with the top od the horizontal cornice, and the capitals of the columns are taken from the same course with those forming the rear angles of the pier. Moreover already the plan of their bed joints leads to such a harmony of the heights and the borders conceal the vertical tendency.

Removal of water from the flying buttress.

The removal of water from the channel of the flying buttress, of which we have already spoken, must either be through a pinnacle or be led around the gargoyle projecting at the middle or angle of the flying buttress.

Only on the church of S. Katherine in Oppenheim does the channel passing through the pier divide inside it to both sides, e ending at the sides of the pier, in openings given at a in Fig. 901 so that the water drops over the wash and drip moulding to the gutters of the roof of the side aisle.

By the reparations in the years 1878 to 1889, according to t the statement of Professor Baron von Schmidt at Munich, the old water channel was restored again in all its parts, but the water was conducted in leaders to prevent the danger of leaks from metal piles laid in stone gutters.

Calculation of stability of the buttress system.

Although the conditions of stability have already been stated in the Section on Abutments, it will not be omitted here in the bays of the basilica to give a fuller understanding of the course of the calculation by a simple example.

Example. Calculation of thrust of the flying buttress.

The same example (Fig. 394) on which was based the calculation of a hall church on p. 154 and 376, may now be regarded as pertaining to a basilica to be erected in brick. The vaults may exert the same thrust and weights given on p. 154, the outer walls of the side aisles being only 2 1/2 bricks thick = 65 cm and 11 m high, the clearstory walls being supported by pries of sandstone and have a height of 22 m from the floor to the gutter, but on the contrary having a thickness of 3 bricks = 78 cm, that already exists in the dividing arches. The side vaults have none,

that now the buttress receiving the flying buttress has the cross shape shown in Fig. 910 instead of the simple oblong plan.

Similar forms result on the choir buttresses of certain works, like the cathedrals of Cologne and of Amiens from the junction of the chapel walls w th the buttresses, so that as shown by F Fig. 911, these walls are attached to the buttresses as strengthening wings a. Meanwhile this arrangement has the disadvantage, that the buttress has an excessive depth and thereby obstructed the view of the high choir, as well as proved by comparison of the choir design mentioned with that of Beauvais. For on the l latter the buttresses have retained the rectangular plan and thereby have ensured the greater effect of the clearstory, which is even increased, as instead of being planned as a polygon this is a semicircle, and hence the crowning roof cornice with its grand curve represents a complete unity.

Horizontal division of the buttress.

The junction of the back of the flying buttress leads to a h horizontal division or termination of the buttress, and also as a rule is fixed a second division by the junction of the arch itself, thus being the height of its ground line. This principle of a horizontal division of the buttress dominated by the flying buttress is found indeed in the freest treatment on even those of gologne cathedral, on which verticalism predominates in such a detailed way.

On the contrary we meet with a decidedly different system on the cathedral at Rheims (Fig. 894), where the proper buttress that is joined by the flying buttress stands on a massive small tower, which consists of a solid substructure adorned by blind arches and with columns inserted in the angles, with a colossal shrine of a figure supported by four columns and terminating in a high octagonal spire and four angle pinnacles. There the divisions in the height of the little tower correspond neither to those of the adjacent pier nor to the heights determined by the junctions of the flying buttresses. This system of the attachment of two different portions of the pier, thus a more vertical division is further found, if already less decided on the choir buttresses of S. Ouen at Rouen (Fig. 1083), where the upper flying buttress rests on the lower cornice and its coping at the height of the springing of the arch of the rear part of the pier.

But the inequality of the division in heights of the two adja-

Inserting the values given above as obtained, B = 3020 kil.

Having the required thrust of the flying buttress, then its required weight can be computed, when the equation of moments is established for the probable lower point m, under the assumption that in this case the centre of gravity of the arch and the force G lies about 3 m to the right of M, and the upper point of application is about 5 m above M; G × 3 = 3020 × 5. Hence the weight of the flying buttress must then be G = 5033 kil, i.e., the arch with the loading coping must be $\frac{5033}{1800}$ = 2.8 cu. m in volume, or with a thickness of 1 1/2 bricks = 0.38 m, it must have a vertical area of about 7 sq. m.

It is still possible to construct a perforated arch as shown in Fig. 912 with this small area. If there were practical grounds for a somewhat greater volume, nothing would oppose it with an otherwise correct distribution in the given limits, since t the assumed masonry on the cross arches would offer resistance by its stiffness (increase of Hg) but then the abutment pier w would also naturally require somewhat greater dimensions.

Calculation of thrust with the effect of wind.

It will now be investigated how the flying buttress, whose coping falls 1 to 1 1/2 m below the gutter, acts with a heavy storm of 120 kil per sq. m pressing on the opposite wall.

If it can be assumed that the wind against the roof and wall of the side aisle can be resisted alone by the stability of that external wall, then remains the wind against the clearstory wall and roof.

The wind against a panel 7 m high and 6 m wide of the clearstory wall amounts to 6 × 7 × 120 = 5040 kil, and it has an average point of application at the height of 18.5 m.

The wind against one bay of the length of the roof, that with 60° inclination and 10 m length of slope has an area of 10 × 6 = 60 sq. m, and according to p 163 it amounts to 60 × 92 = 5520 kil, and is applied at the height of the beams, thus at 22 m a bove the floor.

The total effect of the wall and roof is then computed at 10,560 kil with about 20.5 m average height. From this is deductid 800 kil in consequence of a small reduction of the thrust of the flying buttress at the windward side, and further the two middle piers together could receive about $\frac{1000 \times 20.5}{110,000}$ = 0.19 m, that without too great edge pressure, that here is not pursued farther,

is indeed allowable (p. 145 and 155). There would still remain the wind pressure of about 8000 kil, which is transmitted to t the flying buttress, partly by the stiff cross arch and partly by the roof framework of the side aisle.

This horizontal force is much greater than the ordinary thrust of the flying buttress, it would press upward and destroy a simple arch, and it can only be received by the inclined upper coping, which moreover by its high junction against the upper clerestory wall receives the wind where it acts, and thus keeps f from the pier the vibrating overturning moments.

The wind pressure W = 8000 kil and divides into two components (Fig. 912 a), one component falling in the direction of the strut and with the inclination of that at 45° amounts to $8000 \times \sqrt{2} = 11,314$ kil, the other being berpendicular to the former and directed upward and results at 8000 kil, opposing the weight of the clearstory wall and roof with its vertical wind load, and it opposes a high pressure of those parts. The larger force of 11,314 kil coinciding with the direction of the coping of the arch must be safely conducted downward by this coping. It is assumed that the danger of bending or bulging is not to be feared in this case, and thus only the question of the resistance of the cross section to compression at x x is not in question. If with construction in bricks and lime mortar 7 kil per sq.cm is allowed, then the cross section is $\frac{11314}{7} = 1616$ sq. cm, and thus with an average width of 38 cm it must have a depth of 42.5 cm. Construction of this part with cement mortar or by the use of cut stone, these dimensions could be somewhat reduced.

Calculation of the buttress.

Now to be examined is the stability of the prick pier receiving the flying buttress, which for a fixed height of 18 m and a thickness of 1 m may have a lower depth of 3.2 m and an upper one of 2.4 m.

On the buttress act the vault thrust of the side aisle, the thrust B of the flying buttress and the horizontal thrust W = 8000 kil exerted by the coping of the flying buttress during wind (Fig. 912 b), as overturning forces, transferring the following moments to the area of the pier at the height of the floor.

Side aisle, 2160 × 8 =	17,280
Flying buttress, 3020 × 13 =	39,260
Coping with wind, 8000 × 15 =	120,000

Total overturning moment = 176,540.

For the still unknown point of pressure in the ground area w which may lie X m from the rear edge is establisred the equation of moments, the overturning moment just obtained being placed equal to the favorable moment of the vertical forces. The vertical forces are the following:- 1, weight of the buttress, that with 18 m height, 1 m thickness and 2.8 m average depth has a volume of 18 × 1 × 2.8 = 50.4 cu. m, thus weighing 50.4 × 1800 = 90, 720 kil, while its centre of gravity lies 1.4 m from the inner edge; 2, weight of the part of the external wall adjoining the buttress, which with about 20 cu. m volume weighs 36,000 kil, while its centre of gravity lies 0.32 m from the inner edge; 3, the vertical force of the vault of the side aisle acting at the inside face of the wall, that as noted above amounts to 6,840 kil; 4, the weight of the flying buttress of 5,033 kil acting at the rear side of the buttress; 5, the vertical component of the pressure transmitted by the coping (Fig. 912 b) which amounts to 8000 kil, and can be regarded as acting at the inner side. Thus the equation of moments is:--

$90,720(X - 1.40) + 36,000(X - 0.32) + (6,840 + 5,033 + 8,000) X = 176,540.$

Thereby is computed the distance X of the pressure from the inner edge, and X = 2.15 m.

The pressure already lies somewhat outside the kern, but it is still distant 1.05 m from the outer edge. The sum of all vertical loads resting on the ground area of the pier is computed at about 150,000 kil, and the average pressure amounts for about 4 sq. m of bearing ground area of the pier and the adjacent wallto $\frac{150000}{40000}$ = 3.75 kil, and the edge pressure is somewhat more than twice this average pressure, thus being about 8 or 9 kil per sq. cm. This stress in all cases can only exceptionally be allowed for good brickwork; if it is believed that the masonry must not be so strongly stressed, then the pier is to be made somewhat deeper and must then be calculated anew. In our calculations the wind pressure is taken at the estblished magnitude of 120 kil per sq. m of exposed surface; if in consequence of better investigations or of local conditions, greater or smaller values are to be taken, then will the final result be changed to correspond, but the nature of the matter will remain the same. The wind against the clearstory of the basilica should never be

assumed too small, since this usually rises above the neighboring buildings, and moreover the wind is raises by the side roofs against the clearstory. When no wind acts, according to the evidence of the equation of moments now as before established, the pressure lies nearer the centre of gravity of the ground area, so that a nearly uniform distribution of pressure results, nowhere far from the average pressure, that amounts to about 4 kil. If the middle pier is made very slender so that it is unable to receive a part of the wind (as assumed above), then its portion would fall to the buttress, on which then would act a side force of 10,000 instead of 8,000 kil, which would make it necessary to strengthen the pier. Then for the basilica as well as for the hall church (p. 375), the external buttress can take the place of the middle pier, uhen a correct cross stiffening by the middle vault and flying buttress is cared for.. Conversely a very strong middle pier may take the place of a too weak outer buttress. One can generally assume that a correct transverse stiffening that the basilica is stable, if the two middle piers and the buttress opposite the wind are together sufficiently stable.

General remarks on calculations.

Nothing prevents extending the calculation with greater accuracy to further details, which is here made in form as approximate as possible, particularly in following the entire course of the pressure in the middle piers and clearstory walls, including, the framework of the roof, side arches, passages, etc., to test the behavior of the flying buttress and of the masonry on the cross arches in varying strengths of the wind, determining the important enlargements of the plinth and footings by calculation etc. This edition of the Manual has given indications for this in different places, so that it must not be difficult for the designer with some circumspection to satisfy himself properly concerning details and peculiarities, that only appear in a worked out design.

Here comes to us the fear first of all of seeming in any manner to strive for theory and of rejecting to seek for easy ways both for accurate as well as for approximate calculations, thereby showing that we had not yet seen correctly the static conditions of such works, that in contrast to the old masters we had been too much accustomed to take account of the quiet forces, thrusts of vaults, etc., while in quite particular magnitude

are the varying stresses by wind, etc., to which must be devoted especial attention. Reference is again made to the fact, without wind thrusts if necessary, that our greatest basilicas could be erected without flying buttresses, since then by corbelling and weighting the masses equilibrium could always be attained.

Many of our statements are first attempts, it must be confessed, which it is hoped may be further perfected. In this opportunity unfortunately we cannot fail to remark, that many ground factors on which our calculations must be based, require further explanations, and to these belong the allowable limits of stresses, the elasticity and resistance to bending of the kinds of stone and mortar, the pressure of wind, its effect of impact, its diversion and its gliding on inclined surfaces, and many other matters. Recently it is gratifying that theorists and practicians appear to turn rather to these domains.

4. Development of the Triforium.

Section of the triforium.

Fig. 913 represents the cross section of the church with buttress system, as it results from the preceding, and at a is the passage arranged before the clearstory windows, the triangle d b c is the roof of the side aisle, and e is the little column supporting the flying buttress, which stands on a pier carried through the interior of this roof. If we now base this on definite dimensions and calculate for the widths in the clear of about 9 and 5.5 m, for the middle and side aisles, the pier 1.35 m wide, the projection f g as 30 cm for the round above the capital of the pier, a window wall h i being 45 to 50 cm, width of passage a 40 cm and the column e 30 cm, the total width e x is about 1.5 m, and hence the necessity of either corbelling out the pier supporting the column e, or setting it on the springing of the vault of the side aisle, by a distance which increases with the reduction of the width of the aisle and the width of the lower pier, since the width of the passage must be constant.

Accordingly as our Fig. shows, there results at the height between the crown of the dividing arch and the floor of the passage a thickness of the wall of at least 90 cm, and about 1.7 m for the aisle pier at f k, since the column e also has a base.

Economizing the wall by a triforium.

Then if such a thickness of the pier above the passage and

through the buttress system would be superfluous, it is at least of the same dimension at the height of the joining of the roof. No les superfluous is that heavy thickness od the wall on the dividing arches, since it becomes actually injurious by the loading, and the thrust of the dividing arches is substantially increased thereby, which may even compromise the stability of the crossing piers. We shall only mention here, that the weight of such a wall mass is more than six times the part of the vault loading each pier, and that to us has appeared on a new building even before completion an important danger resulting from neglect of this increased weight. Reducing this wall mass therefore seems directly, lessening the thickness above the pier as at least indirectly required. Both requirements would be expressed in the most commonplace way to an eye as avoiding economy. But the open demonstration of all structural conditions forms the life principle of Gothic architecture, and it has in this case led to the arrangement of a passage opened to the middle aisle within this thickness of the wall, i.e., to the triforium.

Placing the back wall of the triforium.

Now assuming in Figs. 913 and 913 a the floor slab of the upper passage as extending through the thickness of the wall beneath the window sill course, the triforium is formed by an arcade standing on the inner ends of these slabs, which is placed on the horizontal cornice above the dividing arches, and t the walls closing the passage at the outside. If we now assume for the arcade, passage and back wall thicknesses of 30, 45 and 30 cm, which are to be regarded as about minimum dimensions, t there results a thickness of 1.35 m, which the width of the dividing arches exceeds. Therefore occurs the need, according to the total dimensions, for extending the back wall of the triforium entirely or partly between the piers above the junction of the compartment turned against the dividing arches and placing thereon a concentric arch, so that their weight will be transferred to the rounds in the side aisle. This necessity disappears, as results from what is said on piers, with a widening of the dividing arches resulting from the total dimensions. To illustrate this we add in Fig. 913 a a perspective view of the entire construction.

As the cross section in Fig. 913 b shows, the window wall projects beyond the outer face of the triforium, on account of its

greater height needing a greater thickness than the columns of the triforium, and rests on the floor slabs of the upper passage. But the unequal thickness assumes an entire separation of the columns of the triforium from the mullions from the window, and ceases when the triforium is treated in a sense as a continuation of the window wall. For strengthening, the arrangement of a second course is preferable, or at least the separate ashlars laid from the columns to the back wall, which naturally lie under the joints of those slabs. Then in the upper surfaces of these are cut little grooves under the joints mentioned, which conduct any water flowing through them to the outside. The roof of the side aisle joins beneath the projecting moulded edge of these floor slabs, which then is also broken around the pier, as seen at a, Fig. 913 b, indeed in a direction following the slope of the roof, thus also ensuring to the latter the junction with the roof. The height of the roof and hence also that of the triforium dependent on it as a rule results greater than seems required by the passage leading through the pier. For connecting the halves of the pier separated from each other by the passage are therefore placed the tie stones b in Fig. 913 b over the height of the passage, and the space over them can be walled up.

Elevation of the triforium.

Relation between triforium and window.

The stone beams according to the usual arrangement are replaced by arches extending from column to column, to whose form as well as position of the columns with regard to the side arch r rounds, there applies what is stated on arcades. This simple uniform row of columns connected by arches predominates in the e earlier works, as in the cathedrals of Laon, Soissons (Fig. 915), Rheims, Chartres, Notre Dame at Dijon, and on the cathedrals of Limburg and of Bonn in Germany. Instead of simple columns are sometimes piers composed of several columns, as in the choir of S. Benigne in Dijon, or mullions without capitals continuing the mouldings of the arches, as in the aisle of the same church (Fig. 916). The smaller height of the triforium then causes that the number of divisions exceeds the number in the window above, and indeed first so that a direct relation does not occur. Thus in the choir of Rouen is found a triforium in 6 divisions below a window in 4 parts, while usually as in Chartres and Rheims, the former doubles the number of the divisions of the latter. But

also the already mentioned difference in dimensions in the separation between window and triforium excludes the necessity of placing window mullions over the column of the triforium, if already from a certain relation of both parts is to be sought the advantage of a uniform division; the endeavor to bring them into harmony therefore leads to divide the arched openings of the triforium into main and subordinate divisions, i.e., to first arrange larger middle and wall columns, connecting these by arches, dividing the spaces thus formed by smaller columns connected by arches, then employing the system of large and small window mullions (Figs. 917, 918). Beneath the window in 4 divisions in t the aisle at Amiens the triforium consists of two such groups each composed of triple divisions. The important height of the triforium already caused by the steeper position of the roofs of t the side aisle might make such an arrangement advisable, by which the excessive height of the columns would best be avoided.

On the choir at Meaux the considerable relative height of the triforium resulting from the small length of the sides of the polygon even leads to the combination of both groups under a c common pointed arch, an arrangement that naturally would be impossible with a greater length of bay. The combination of window and triforium becomes particularly intimate, when either a doubling or an agreement of the number of divisions exists, but always the larger columns of the triforium stand beneath the larger mullions of the window. The system of forming groups then leads in the triforium either to alternation of larger and smaller columns, as in S. Gudule at Brussels (Fig. 917), or to a division analogous to the window mullions in a compound system.

Now since by the alternation of large and small mullions the thickness of the window wall becomes unequal, it may appear indicated also to enlarge the little columns in the front wall of the triforium standing beneath the larger mullions to harmonize with the latter. Therefore the window and triforium are brought more into accord, so that the large window mullitins extend down to the sill of the triforium or to the capitals of the larger columns of the triforium.

Therefore in the first case, if Fig. 918 a represents the plan of the large window mullion with the indicated smaller ones, the first also corresponds to the primary and the second to the secondary columns of the triforium. But the small as well as the

large window mullions also contain the inside moulding forming the groove for the glass, which in this form is superfluous on the columns nf the triforium and correspond to the little column c on theml The latter then in the development of the elevation of the triforium can only be utilized for the arrangement of little tertiary columns c′, which also leads to the subordinate division not existing in the window, i.e., to the doubling of the number of divisions of the window for the triforium. Accordingly the window sill receives only the thickness of the small mouldings, and the projecting edge moulding either extends down to the lower column of the large support (Fig. 922) or is broken around it. Examples of such triforiums appear with windows divided in 2 parts in the cathedral of Beauvais (Fig. 847), with tose in 4 parts in the nave of Chalons (Fig. 918) and the minster of Strasburg, with 3 parts in the transepts of Chalonsa

We call attention here to the peculiar corbelling out of the columns of the large mullions in the last Fig IX, vhich has its reason that in the transept the corresponding columns at the wall jambs do not stand on the floor of the triforium as in t the side aisle (g in Fig. 918), but extend down to the floor of the nave (Fig. 919), and therefore only these corbellings were to be obtained as bases for the equally projecting middle columns.

Combination of triforium and window.

In late works always increases the endeavor to make the triforium a continuation of the window. We mention instead of many only the example of S. Peter in Louvain, where the window mullions extend in completely unchanged form through the cornices denoting the sill of the window and the floor of the triforium even down to the dividing arch, naturally as blind mullions between these and the triforium. Below the cornice they are connected by arches with cusps and above the floor of the triforium is a tracery balustrade consisting of separate quatrefoils.

The colonnade of the triforium in the nave of the cathedral at Rouen is replaced by segmental arches turned between the inner piers. (Fig. 920). But the effect of the whole is violent in the sense with all its originality.

Triforium with smaller width of window.

We have hitherto described the arrangement of the triforium only for those wide windows occupying the entire length of the bay. For a smaller width of the window the colonnade can either

stand beneath the wall surfaces remaining beside the window, as on a little church at Rheims (Fig. 9_1), or only within the width of the window. The latter arrangement in combination with the before mentioned extension of the mullion-columns of the floor of the triforiumis found in Notre Dame at Chalons (Fig. 922) and S. Remy at Rheims.

The close spacing of the little columns serves at the same t time for the complete safety of Those passing along the triforium, and therefore at least on the older works as a rule no balustrade is placed between them, but sometimes instead of it the plinth of the columns is raised above the floor, that is either effected by raising the moulding over the didided arch, by a s steeper wash, or finally by the arrangement of a low parapet w wall above it. But the omission of the little columns, as in t the cathedral at Rouen, entails the need of a balustrade.

Window over the back wall of the triforium.

When we proceeded before from the assumption of an external passage before the clearstory windows, the triforium is also s still found with the same right, if that upper passage lies in the interior, as on the churches of Burgundy, and there is only the difference that the upper window wall is placed above the back wall of the triforium, and therefore all relations between its columns and the window mullions vanishes.

Simplified designs.

With lesser proportions of height or simpler construction then also indeed disappears the passage and with it the colonnade of the triforium, and there is found inside passage entirely o open over the dividing arches. Such a design is shown by the c church of S. Maria at Lübeck, where this passage has a tracery balustrade. A further simplification of the system is shown in the same church, where also the openings through the piers vanish, so that the separate balustrades over the divided arches are only connected through the attic over the side aisle, into which they open by doors. If now in the present case according to all probability a concession is to be sought to brick construction, then also in stonework the smaller dimensions of the whole and hence also of the piers, make those openings impossible. Therefore are found on the triforiums of S. Ouen in Rouen, otherwise constructed with columns after the usual system, the same arrangement as at Lübeck. In the very clever way in the

cathedral of Limoges, likewise avoiding the opening through the pier, and then the passage of the triforium leads around it in a corbelled semicircular balcony above the vaults of the side aisle. The upper passage is then found on the platform covering this balcony, and accordingly there also disappears the opening in the upper pier, as well as the arrangement of that external free column, and hence the flying buttresses rest directly on a buttress projecting from the upper face of the wall.

A further reduction of the design of S. Ouen and in a sense that of Lübeck is found in certain German works, where the window jambs and mullions, yet the latter only in half their plan extend down to the wash of the moulding over the dividing arches, and the attic over the side aisle opens to the interior through doorways between the blind mullions. While there also those attics serve to connect the separate divisions of the triforium with a passage, they here directly form it.

Strictly taken, logic is here in favor of the last arrangement, yet otherwise the effect of that high window of the middle aisle with its lower half blind and directly above the dividing arch is far below that, which results from the insertion of that row of columns as the richest conceivable frieze in purely formal conception, which by the contrast of the columns of the triforium with the piers of the nave and the rounds, the graceful arches of the same with the wide spans of the dividing and window arches, the greater part first reached its full effect or was thereby enhanced, this would be clear even without consideration.

Moreover the motive of the insertion of such galleries of columns between, over or under higher stories with greater designed parts is one of the happiest occurring in the history of architecture, and beside the position designated here, also reappears elsewhere frequently in churches and secular buildings. We refer to the Tuchhaus in Louvain, where it extends beneath the windows of the pricipal story. Even the form of the doge's palace in V Venice might be referred to it. But the root of this arrangement is to be sought in those so-called dwarf galleries above the s springings of the vaults which characterize the Romanesque buildings of the Rhine provinces.

Triforiums with windows in the back wall.

Triforiums in the choir and transverse aisle.

If triforiums originally came from the plan of shed roofs over the side aisle, they are also found on those parts of buildings where this cause is lacking, executed in complete or slightly changed form. Indeed they must exist thereby to attain the connected purpose of securing a passage. Such parts of buildings are the choir and the transepts for plans with a single aisle, but also the gable walls of the west end and of the transverse aisle. Only here the absence of the roof leads to the plan of windows in the back wall of the triforium. The latter then correspond in their arrangement either to the arched openings of the triforium, so that they reproduce them externally with the addition of glazing and the parts required thereby, they are in a different form, or finally are also arranged according to a different system. Thus on the transept gables of Rheims the back wall on each of the three triforiums spanned by round arches, but in the choir of Notre Dame at Dijon the entire back wall behind the triforium divided in two parts is opened by a great round window, while at the west side of the transepts at Compeigne is found the peculiar arrangement represented in Fig. 923, whereby there is found in the back wall behind the three arched spans of the triforium two pointed arched windows separated by a slender middle pier, and further for the first arrangement is afforded by the example in that transept at Chalons represented in Fig. 932. It may be that the similar division is more favorable to the effect of the glass painting in these windows, and thus we must award their rights to the contrasted lines obtained by a diversity of the system as in Dijon and Compeigne.

Transfer of the windows to the triforiums of the nave.

The magnificence of the painted glass by which the triforiums described above outshine their sisters in the nave might then lead to the endeavor to ensure to the latter the same effect. But in the nave the design of the window compelled a change in the roof, thus either a substatute for the shed roof or a terrace as in Oppenheim, or by a gable roof with a gutter arranged along the clearstory wall as on S. Denis and the Strasburg minster.

If it was then a little too strong to alter the entire design of the roof, and to transform it into a form less advantageous for the easy presentation of the entire building, as at least the latter certainly is, only to obtain the effect of some stained glass, for which the entire system of the building otherwise

offered sufficient space, then shall we see how this arrangement of the roof led to the omission of those parts for which they originated, for in both was lacking the determination of the h height of the triforium, and therefore the particular cause for its existence, and no reason existed longer, not to continue the window down to the terrace or the gutter existing between the roof and the clearstory wall. If then the height so obtained a appeared too great, it could be reduced and moreover the height of the middle aisle, thereby securing an actual advantage in material respects, whereby indeed the interior became poorer and the effect approached that simple arrangement of an equally high aisle with two rows of windows over each other described on p.356.

As an example of the last kind with gable roofs still belonging to the 13 th century, we mention the cathedral of Toul (Figs. 850, 850 b). The same arrangement in connection with a terrace is found on the church S. Katherine at Oppenheim dating from t the 14 th century.

Thereby the terraces over the side aisles in Oppenheim, this most convenient means of communication, lead to the omission of the passages fulfilling the same purpose. Meanwhile with the plan of a gable roof and the thereby required gutter for water along the clearstory wall formed a passage and ensured access to the windows of the middle aisle, as then generally the gutter appeared in the place of the upper passage above the junction of the shed roof, and could be formed about as in Fig. 924. But we admit ourselwes unable to mention any example of this kind.

5. Vaulted galleries over the side aisles of the basilica.

The galleries of the basilica differ from those of the hall church (p. 381) only in this, as shown by Fig. 926 b, that above the arches by which these galleries open into the middle aisle, still is the height required by the shed roof and the clearstory, but on the exterior and above that roof are found the flying b buttresses.

Openings of the galleries into the middle aisle.

We have already referred above (p. 382) to the arrangement of altars in those galleries, whereby these are elevated above the importance of balconies and assume a more iddependent position. Accordingly as a rule there is found in the most important works of the kind, like the cathedrals of Laon, Noyon and Paris, collegiate church at Mantes and the cathedral at Limburg, the arran-

arrangement leertainly explained by esthetic reasons, that the span of the arch is divided into smaller openings by one or two columns. These esthetic reasons consist in that the repetition of two nearly equal arched openings over each other, as the elevation of the nave of Rouen (p. Fig. 920) shows, where however the galleries behind the upper arches are wanting, an ugly and tiresome effect must be produced. The arrangement of little columns is so developed in Mantes most beautifully from the members of the dividing arches and that corresponding to the main piers, that these columns and the arches connecting them as well as the tympanum resting thereon correspond to the lower ring of the dividing arches and the rounds supporting the latter, and hence the membering of the lower pier is entirely the same as that of the upper (Figs. 926, 926 b).

Vaults of the galleries.

The vaults of the galleries mentioned as a rule correspond to those of the side aisles. Only in Mantes do we find in a very peculiar way that the bays over the choir aisle are spanned by radiating tunnel vaults. These tunnel vaults are almost constructed after the antique fashion on stone beams, that are supported by two little columns standing on the lower cross arches. The trapezoidal plans of these bays then led to no raising of the tunnel vault externally, but by the horizontal position of the top and a prigressive alteration of the arch lines, as represented in Fig. 926 d.

But there the side thrust of the first tunnel vault at the beginning of the curve of the choir is met in a very skilful way in that the bay spanned by the cross vault, the quarter of the compartment concerned is transformed from the cross vault to a tunnel vault (Fig. 926 b).

Over the choir aisle the arched openings of the gallery then become so narrow, that the division by columns in front is impossible. But still this system is expressed, by the insertion of a smaller arch within a higher one, whose members correspond to those of the dividing arches in the nave, and thereby as Fig. 926 a shows, coincidence with the lower dividing arches is avoided.

Over the gallery then lies the roof on the wall of the middle aisle, and thereby is given the motive of the passages and the arcades in the triforium, just as by the ordinary cross section without galleries over the side aisles.

Passages above the galleries.

Since the purpose and origin of these passages is nowisi connected with that of the galleries, the existence of the latter affords no ground whatever for their omission, and the cathedrals of Laon, Noyon and Limburg show, that these little arcades between the arches of the gallery and the window story produce a very tasteful effect. Indeed in the works mentioned the arches of the gallery are divided by only one little column, and not by two as in Paris and Mantes, thereby avoiding all competition with the arcades of the triforium. In the cathedral of Paris was found a different arrangement in the original building (Viollet-le-Duc, II, p. 289), which substantially amounts to the same thing and produces a triforium almost purposely like that mentioned above.

Although here especially the hoof over the gallery is made so flat, that it does not afford space for a triforium, so that this is obtained by making the arches of the gallery opening i into the middle aisle and thus the junction of the same cross vaults much lower than the outer side arches of the same vaults, about as shown by the cross section shown in Fig. 889. Only no passage in the height thus obtained is formed in the thickness of the wall, since in general the entire buttress system was not intended for such, though the space over this depression of the gallery vault afforded such, which then received great round o openings connected with the middle aisle and filled by simple tracery. In the church of Mantes, whose section is shown by Fig. 926, the buttress system is likewise calculated for no passage in the triforium, and the dimensions are so moderate, that an arrangement as in Paris could not be executed. Besides the construction of the entire church is very simple and particularly recalls Romanesque architecture by the small size of the windows.

By the arrangement of vaulted galleries the piers and walls of the middle aisle further obtain greater safety, that in Paris is even increased by the flying buttresses above the vaults and still beneath the roof. But further this has led in the works mentioned to a lesser height of the upper clearstory, so that only single flying buttresses are found above the junction of the roof of the gallery.

Galleries in the transepts.

If we now ask concerning the influence of the galleries on

the form of the transepts, no conclusions are given by the French works named, for in Mantes the transverse aisle in general is wanting, but is single-aisled in Paris and Noyon, and hence galleries are lacking therein, or rather those placed over the side aisles between the nave and choir open into the transverse aisle just as into the middle aisle, without being connected w with it. Also even the usual plan of transepts with several aisles, this connection before the gable walls could be made only by open galleries above as in Laon. Extending the side aisles around and thus the vaulted galleries on the gable walls are found nowhere. Therefore the gable walls are only carried so far in sympathy with the design of the galleries, as these have double window stories over each other and above the triforium, While they are removed from all such influence in Paris. Only the cathedral in Limburg shows in the peculiar construction of its choir and transverse aisle at least a substitute therefor. The two last parts are surrounded by side aisles and passages, which are only half the width of the side aisles in the nave, and also but a fourth the width of the middle aisle, since the vaulting system of the hexapartite vault is of square form. Over the angles of this gallery on the transepts rise then two towers flanking the latter. Accordingly as shown in Fig. 925, the system of the form of the cross section in the transepts appears in the same way as in the aisle. But the possibility of this construction is based on the plan of the vault explained on p 414, by which a pier stands at the middle of the gable wall, a and was dropped in the plan of the ordinary cross vault, or rather must lead to the arrangement of a balcony open above and in connection with both galleries, as found in Laon.

6. Cross section of simple choirs, transverse aisle and gables of the basilica.

Choir.

Extension of the window of the triforium.

As before stated above, the entire division in height, thus the widdow stories of the middle and side aisles and the triforium, also in the single-aisled portion, so that also here if a passage is found before the lower windows, two internal and one external passages are formed according to the usual system.

Triforiums.

Each lower passage, that otherwise is usually wanting because

of the small height of the sills of the windows in the side aisle, and that is to be regarded rather as a peculiarity of certain regions like Burgundy, Champagne and the upper Rhine, results in the choir in a certain way from the arrangement of the triforium, in so far as represented in cross section in Fig. 9., it was elsewhere necessary to turn an arch b between the buttresses, which then changes place with the lower window wall, so that the arrangement shown in the side Fig. 9 / a results w with a lower passage a. As examples of this kind we mention Notre Dame at Dijon and the cathedral at Regensburg. From Fig. 9?7 also an external passage could meanwhile be constructed.

If now in Fig. 927 a, as this is also the case in Regensburg, and is likewise first results from the construction, the floor of the triforium is only formed of slabs laid from the arch to the window wall, there results one of the cases mentioned on p 851, acoording to which the pointed form of the window is not exactly the one required. Yet it is found in Dijon, but in one panel and without mullions, as then also in the middle aisle t the horizontal termination is only obtained by placing 3 smaller pointed windows side by side (Fig. 848). On the contrary in Regensburg the square inclosed by the buttresses and that floor slab is filled in the richest way by arched tracery, whose scheme consists in a pointed arch spanning the separate divisions by mullions, so that above the spandrels and below the disk it is opened in other forms of tracery.

In Notre Dame at Dijon as in other churches of Burgundy, the windows do not extend down to the floor of the passage as in Regensburg, but are rather raised above it by a plain wall surface. In the choir of S. Benigne at Dijon is then found a further reduction of the system, so far that the lower light stories, and hence also the passage appertaining thereto and also the upper one found above the triforium are omitted, so that the projection of the latter from the window wall is found covered by a wash.

Likewise there is sometimes wanting as in S. Leger in Soissons the window in the back wall of the triforium, so that both light stories on the exterior are separated by a plain wall surface corresponding to the height of the triforium.

Transepts.

What is said on the plan of a choir with single aisle applies in the same way to the longitudinal wallu of the transpts and only according as a rule the length of the polygon axceeds the length of the bay, is the number of the arches of the triforium and also the width of the window increased. Hence the length of bay in the transverse aisle always is less than in the middle aisle, as the case in Chalons, where the windows are divided in the former into 3 parts, in the latter in 4.

Rounds and buttresses.

By the junction of the single-aisled transverse aisle with t the three-aisled nave results certain special arrangements of rounds and buttresses to which attention is here called.

For example Fig. 928 is the plan of such a part of the crossing arranged about according to the system of Chalons, therein a being the crossing pier, b the opposite wall pier, c the side aisle, d the middle aisle, and passages are to be arranged before the windows of the side aisles, which then continue before the lower windows of the transverse aisle. Now the wall pier at e requires three rounds for the wide cross arch supporting the upper wall, while the simple cross arch meeting it at f only needs a single round. To equalize the resulting inequality of the number of rounds on the sides c g and f h and at the same time produce a regular plan of sufficient strength, at the angle h project two rounds but only one at the angle g. From the former then extends down to the floor the round 1, as well as the corresponding 2, that bears the cross rib, and since the latter in the transverse aisle already rests on the round 3, they form the outer columns of the wall pier (Fig. 919), so that for the middle one with the same projection there is lacking a base, and therefore occurs the previously mentioned necessity for corbelling them. (In Fig. 919).

By this peculiar arrangement is then solved the inharmonious contrast of the single-aisled to the plan with more aisles in the happiest manner, while the next bay of the transverse aisle, whose upper wall above the dividing arch l m exactly like the middle aisle, of which Fig. 918 represents a bay, comes to stand over the dividing arch h o, so that thus here corresponding to the round 1 and likewise to the rounds 5 and 8 continued in the window mullions, which belong to the dividing arches, extend above these in smaller size as seen in Fig. 918 at g, and accom-

accompanying the window mullions, but here the corbelling of t those belonging to the middle mullions makes equally projecting little columns superfluous. B

By reason of such peculiarities, that are never capriciouson medieaval works, it is necessary to call attention to this not entirely banished conception, which see in caprice the nature of Gothic architecture.

If we now return to our Fig. 928, then i k gives the thickness of the upper window wall and of the larger columns of the triforium, so that the dotted lines s s x determine the width of the triforium and the thickness of its back wall.

Over the junction of the side aisles or of the side choir, the pier in question between the two windows, only aside of being reduced by the passage, receiving the diameter i k + k t is nowise sufficient to oppose the thrust of the vault, but for the plan of a buttress at right angles standing at this place, a s sufficient basis is lacking on account of the passage. For this reason the pier in question in Notre Dame at Dijon is set diagonally, a position that is certainly peculiar above the junction of the side aisle, and its appearance is not explained at the first glance.

If we now assume that the passage before the lower windows resulting from the plan with single aisle is found only in the transverse aisle and not in the side aisle, then occurs the arrangement of the changed buttress, closing at the same time a part of the window of the side aisle concerned, or the necessity of a flying buttress, that however strikes the side of the nearest buttress, and hence either a strengthening of this or a wider span to the next buttress is required. All these differences would be solved in the easiest manner by the plan of a hexapartite square cross vault adjoining the middle square, occupied in Fig. 928 by the two oblong bays of the transverse aisle, whereby at f would strike only a bisecting rib, whose thrust is substantially less.

Gable Wall.

The various divisions in height continue in an entirely similar way, at least on the larger and perfectly developed designs, also on the gable walls of the transverse aisle. With the adoption of the system of bisecting ribs for the parts concerned, as at the cathedral of Limburg and the collegiate church at

Wetzlar (Fig. 936), also as Fig. 929 shows, the outer bay of t the transverse aisle is divided in 7 parts, and there generally results for these gable walls substantially the same arrangement as for longitudinal walls, so far as their width is now divided in two parts, each of which nearly corresponds to the former side of a bay. But with the dropping of this Early Gothic arrangement the changed proportion of width leads to a certain peculiar form of window story.

Upper window story.

What first concerns the upper window story is, for the general proportion of it to be an approximate equality of width and height, or even a predominance of the former, and hence the design of a pointed window filling nearly the entire width and divided by mullions, on which the ground line of the window must be that of the vault, would be made substantially heavier. It is here the ratio of the space, which on the assumption of a more concentric plan of window first indicates that of the wheel window, aside from the fact that it also in purely formal respects is the most suitable to place in the different architectural form of this gable wall.

Wheel window.

The first arrangement consists in placing the centre of the wheel window at the height of the base of the vault, whereby there is a crescent area between the circle and the side arch and between the circle and the covering of the triforium remain two spandrels, which if the radius of the circle does not quite agree with the height of that covering from the top of the capital of the round, would be stilted by a rectangle. On the older works like the cathedral of Rheims and Notre Dame at Dijon (Figs. 9_3, 9_4), the surfaces of the differences inside and outside are plain walls and essentially contribute to the quiet effect of the whole. Those crescent surfaces above are then on the transepts of the cathedral of Amiens therefore made higher, so that also the side arch is a stilted semicircle, and hence the horizontal diameter of the concentric wheel window is raised by the amount of this stilting, and thus the whole requires a lesser height. But the last consideration did not control in Amiens, but exclusively that of a perfect solution of those difference surfaces.

But on most works the wheel window is set in the pointed side

arch, so that those crescent surfaces above are either simply opened or are filled by forms of tracery. The omission of the lower spandrel was then easily effected in the same manner, and meanwhile was made essentially more difficult by the addition of that rectangle, which men could not decide to leave unbroken on the richer works. To fill the latter was offered the arrangement of a system of mullions. We believe that it can be assumed from several analogies, that in modern times the solution in question would have chiefly consisted in this, that the parts of this filling divided by mullions and spanned by pointed arches could have been adapted to the circle by increasing the heights at both sides like organ pipes. Such an arrangement causes a monotonous and bad effect with a greater number of the divisions. But in the middle ages the sense of form was far more developed than at present.by the continual consideration of correct art works, and accordingly the design was richer. And just in the solution of such small difference areas is expressed most clearly the peculiarities mentioned. Therefore we cannot omit a reference to two entirely different species of the arrangement in question.

Thus on the transverse aisle at Amiens belonging to the 14 th century, that rectangle under the circle is separated by a horizontal division, and below this by a system of 8 pointed bisected blind arches, but the spandrels by two corresponding to two of those and filled to the circle. The entire arrangement is only clever, and not exactly talented, and already shows the beginning denial of the wheel window, that in a sense only occurs as the dominant part of a great round arched window. We compare it with the corresponding one of the transept of Chalons, which in magnificent design and bold execution scarcely has its equal (Figs. 932, 932 a). Here the side arch remains as a pointed arch, and the entire area enclosed by it down to the floor of the triforium is filled by a window, whose form is dominated by the inserted wheel window in a decided way, although its diameter is less than the span of the side arch. Then there is that mentioned on p 407, the motive employed in the aisle for lowering the little columns of the longer window mullions to the floor of the triforium and executed in a manner, that two of the panels bordered by these little columns are added to the outer circle of the wheel window, whose pointed arches are placed at the heights

of the capitals of the rounds. The little columns thus strengthen the triforium in these parts and here also determine the diameter of the wheel window. The space remaining between the wheel, the top of the triforium and the columns mentioned, then instead of being a system of mullions as in Amiens, is here filled by 5 quatrefoils adapted to the circle, and therefore filled toward the middle by quatrefoils diminishing in size. The membering of these latter is secondary, i.e., they lack the strengthening w which the columns mentioned and the outer round of the wheel window corresponding to them afford, which latter therefore forms a projection before the quatrefoil only furnished with a plate and chamfer like simple window mullions. Accordingly the quatrefoils support the lower half of the circle, or rather stress it and present the yielding of the separate pieces in a centrifugal direction. The same system is executed outside, but only with the difference that those little columns end at the stone slabs covering the triforium and therefore are much shorter than in the interior. The windows of the triforium again correspond exactly tn the internal spans of the arches, and receive a particularly rich treatment by the crowning gables.

Windows with pointed arches in the gable.

On later works the wheel window is found to be supplanted by an ordinary pointed window, indeed adorned in the richest forms by mullions and tracery, thus a characteristic arrangement for this place by such a one that can occur everywhere. Meanwhile examples of this kind are already found in Early Gothic works like S. Leger in Soissons (Fig. 935).

In later times men proceeded to proclaim the window in the gable, that is found in the richest manner in the cathedrals of Cologne and of Meaux, as characteristic of the German Gothic and forming the proper consequence of the system. Only so much of this is true, that the origin of most German works, at least of the richer, falls in times in which even a certain exaggeration of verticalism was intentionally sought and that exaggerated consistency down to all details. The system of Gothic construction leads with entire necessity to a predominating vertical effect of the whole, which however in the simplest of the earlier works, as shown in Figs. 933 and 934 representing the transept of Notre Dame at Dijon, is already just as powerful as in the likewise great wheel window, indeed contained as the chief

object in the west end of the Strasburg minster, or that of Cologne cathedral. But the assumption that this grand character of the whole is carried out in its details, and that all more neutral forms must be excluded applied with entire necessity to the removal of all circles included in tracery, and hence led to the forms of the English perpendicular style, in which certainly the round window was everywhere supplanted by the pointed window, but also the separate divisions of the tracery presented only proportional repetitions of the main form of the whole.

While in Cologne the side arch in the transverse aisle is also a window arch at the same time, and the triforium yet retains the simple form of an arcade balustrade, there is found at Meaux a more affected arrangement, where the proportion of height does not permit a similar development, whose system we represent in Fig. 931 from a hasty sketch. Here the width of the window divided in 8 parts and filled with rich tracery is about a third l less than the span of the side arch, and thereforeits ground l line is raised above that of the latter. The triforium is approximately of the same width and is then diwided in 4 panals c crowned by gables, and each of these is again bisected by a middle mullion.

The passage above the triforium is also found inside, and like the triforium is furnished with a tracery balustrade. The height below the triforium corresponding to the side aisle, in which should be continued the window story of the latter, is then spanned in the full width of the transverse aisle by 3 divisions with pointed arches and crowned by gables on 4 pier bodies set diagonally and crowned by pinnacles, the gables being again divided in 4 panels by a system of large and small mullions, about the lower third of which is cut off by a horizontal member corresponding to the window moulding, in which however the same system of cullions extends to the floor, thus representing an arcade.

If we also compare this happily designed system to that of Chalons, there results a substantial difference characterizing the different style periods. Here is seen the endeavor to unite into a vertically acting group two stories separated horizontally from each other according to their nature, namely at Chalons the triforium with the upper and in Meaux thith the lower window story, or the blind arches replacing it. But in the first place

this purpose is attained in a structural way, for without those little columns extended downward and the arches turned on them, the graceful opening of the space under the rose window would not well be possible. On the contrary in Meaux all was obtained in a purely decorative way merely by the arrangement of pinnacles and gables, which contributed so little to strengthen the construction, that they could be almost entirely removed without injury.

If according to rule the triforium on the transept gable harmonizes with those of the nave, there are also exceptions to t this as in Rheims, where they have the same height but consist of only three spans. The same little dividing columns then bear the front ends of the stone blocks extending to the back wall, which form the springings of the likewise semicircular tunnel vaults.

Lower window story.

For the lower window story the breadth predominates iven more than for the upper one, that for the same heights resulting from the cross section of the whole will not even permit the arrangement of the wheel window, entirely aside from this, that such a repetition must weaken the effect. Thus there remains only the arrangement of several windows placed above each other, as they likewise result from that arrangement of plan represented in Fig. 929 with a separate cross vault. Thus is found in Chalons (Fig. 932) two windows divided in two parts and beside each other, in Rheims and S. Leger at Soissons (elevation in Fig. 935) are three single ones, but five such are in Notre Dame at Dijon. (Fig. 934).

The passages before the lower windows here appear in the same way from the construction, es in the choir plans (Fig. 927). In Fig. 930 let a b be the back wall of the triforium or the lower window wall, then according to the system of Chalons for supporting the triforium arcades, that are necessary with angle piers connected by arches with the middle pier c, which then to permit passage is penetrated or must be replaced by one or more detached little columns according to the division of the width of the arch. If then as in Rheims is also assumed for this passage the before described spanning of the triforium by three parallel tunnel vaults borne by these columns, then a harmony of the division of the window with the arcade thus formed would become a

necessity. But according to the usual arrangement whereby the little columns are only connected by arches and so form a wall, from which the floor slabs are laid to the window wall, can this agreement disappear. - very peculiar arrangement of the last k kind is found in Notre Dame at Dijon (Fig. 9,3). Here are arranged in the interior two little columns connected together and the angle piers by segmental arches and thus forming three divisions, yet behind which in the back wall are actually a very charming arrangement of five slender pointed windows, very horrible to fanatics for greater regularity.

Below the lower window story are then found portals, arranged as generally in the transepts, the doorways as in Chalons (Fig. 9,2). But if the heights resulting from the entire dimensions are not sufficient for the latter, they can also extend into the passage, which then as in the side aisles of the cathedral of Regensburg and of the Liebfrauen church at Treves extends o over stairs rising at both sides.

But greater portals must close at least a part of the windows by their arches and gables. Thus at Chalons of the windows visible in the division in question, only the upper circle in the tympanum of the arch is actually opened and glazed, the lower parts remaining only blind arches. This necessity has then led usually to a complete omission of the arrangement of windows a and the direct adoption of a system of blind arches as in the transepts of Amiens, an arrangement that corresponds to the structural conditions in like manner, in so far as thereby is obtained the required breadth for the design of the upper parts w without excessive wall surface, and with which those of the passage are just as well arranged.

Interior of the portals.

While in Chalons the doorways internally remain without decoration, the transepts of Amiens exhibit one kept indeed in moderate dimensions, but an inner portal with its gable extending into the series of blind arches over it. A greater development of the latter, which must be sought not at all in its greater projection inside, would then occupy the entire wall surface under the triforium and therefore exclude the lower window story. Such arrangements are chiefly found at the western portals. Thus in Rheims the space between the internally visible members of the jamb and the nearest rounds is animated by a system of blind

arches filled with figures in relief and arranged in several tiers over each other, which also extend above the enner arch under the floor of the triforium, and thus form an extremely rich enclosure. In the new transept at Cologne the wall surfaces between the doorway of the triforium are animated by the arrangement of a great number of small niches, which by the corbels placed in them and the canopies over them for places of figures appear characteristic. This is an arrangement which goes beyond the structural condition of economizing a mass, as expressed in the blind arches at Amiens and the internal portal arch of Rheims, and obtains a purely ornamental importance, but even therefore perhaps should have been repeated in the opposite transept, but in entirely but nearly similar form.

Organ gallery at the west.

Certain modifications may occur by the requirement of an organ gallery on the western wall.

The monumental solution of this problem, found inside the western gable of the cathadral at Soissons or the transept gable at Laon, can be termed an extension of the arrangement of the side aisle into the bay of the middle aisle. There came then between the western pair of piers one os two corresponding aisle piers, but each smaller pier stands according to the width of the span, from which extend to the western wall the ribs of the floor of the gallery, and a vault is turned to correspond to that of the side aisle. That with the arrangement of a middle pier the direction of the ribs is to be arranged with regard to an inner portal arch, and may make necessary an inserted triangular vault is self-evident. Meanwhile io thes case would be preferable the arrangement of the portal towers of the cathedral of Paris, where for the sufficiently strong middle pier separating the two doorways are turned the bisecting ribs of the octapartite vault of the lower.

From the entire arrangement of such an internal gallery it follows, that a richer triforium can no longer be employed from the aisle. Yet the design of the triforium itself, or that of a passage in the thickness of the wall beneath the west window may be of great use for access to the works of the organ. That the organ is to be limited in its height as far as possible and is to be so formed, that the existing west window remains uncovered, was already stated earlier. But this care may lead to pla-

placing the vaults in question lower than those of the side aisle.

For more on the combination of the western or a transept gable with the towers, see the Section treating the latter.

Simplified arrangement.

The before explained arrangement of the transepts is peculiar to great cathedrals and requires their dimensions. If these are wanting, then the heights are more limited, and there results the necessity of simplifying that system.

First is a reduction of the upper window story, no longer permitted by the arrangement of a rose window filling the width of the transept, or in general a great arrangement of windows dominating the entire surface of the wall in the elevation. Since the predominance of this window story is a condition of the unified effect of the entire system, then must the triforium be omitted on the gable wall of the transept, and the communication of the passage above the triforium on the longitudinal wall of the transept with the latter be made by stair towers at the angles of the transept, while the triforiums themselves are connected by a passage above the lower series of windows.

Such an arrangement is found in Notre Dame in Dijon (Figs. 933, 934), where the stair towers in kuestion are corbelled out directly below the lower passage, and therefore must evidently fisst satisfy the purpose mentioned above. The same simplified arrangement is found on the transept of S. Leger in Soissons ((Fig. 935), where the stair towers are still carried to the ground, just as on S. Martin in Laon.

All these arrangements are based on this, that the upper window on the transept gable fills the height taken by the window story and triforium in the aisle under consideration.

By the arrangement of a portal then, as mentioned above, also the lower window story is omitted. However the horixontal division of the aisle, and wherever possible, also the passage above the height of the side aisles must be carried across on the transept gable, in order to connect it with the whoel both naturally as esthetically tasteful. To moit this division and to fill the transept gable by a window extending down to the sill moulding of the side aisle, strictly taken, with the design of a clearstory as a transept gable constructed to bring into connection a system of aisles of equal height.

7. External Treatment of Gables.

Lower wall of the gable.

Up to the base of the roof there result the different developments of the gable front from what has been said in the cross section heretofore, according to the simpler or richer design thereof. Therefore we first turn to the examples given in Figs. 931, 932, 933.

Small towers or buttresses at the angles.

A means essential to an effective treatment, as the principles of construction already give, lies in a bold handling of the angles, in flanking the gable either by buttresses of increased importance or by small angle towers. Both arrangements then often coincide, for the outline of the building, either occurring connected together as in Fig. 934, or that on the buttresses are set two angle turrets at a certain division of the height, usually corresponding to the base of the roof, that extend above the apex of the gable.

The importance of this treatment of the angle must naturally increase with the opening of the gable wall by that form of window occupying the entire span, where the thrust of the arch loadde by the gable already creates a structural need for sthengthening the width of the abutment. Conversely it is reduced for a closed treatment of the gable wall and is also reduced with a smaller width of window to the dimensions of the ordinary buttress, so that then are also wanting those angle turrets extending above the apex of the gable. Yet where the latter are found without the need of strengthening the abutment, as in Limburg and Wetzlar (Fig. 936), since their form in a sense is derived from the form of the plan, thus in the first place from the arrangement of narrow passages across the transept, on the latter from that of the internal angle pier (Figs. 854, 936 a), which permitted the use of this so extremely effective motive in respect to form. Other examples of an arrangement of the same with a smaller width of the window are shown by the cathedral of Meissen and that of Magdeburg.

Blind arches near the upper windows.

The effect of that design of window opening the full width of the gable wall, is so overpowering, that certain designs are explained thereby, which by a different construction approximate this effect by variously treated blind arcades. An example of

this kind is shown by the north transept gable od the collegoate church of S. Quentin, on which the great blind pointed arch enclosing the wheel window is adjoined at each side by a smaller one filling the spaces near to the buttresses, which are separated from the great one only by the little columns, supporting t the arched passage. Even more plainly is expressed the endeavor mentioned on the south transept gable of the collegiate church at Colmar, on which at each side of the pointed window in 6 divisions filling about 2/5 of the width of the gable, is a blind arch entirely separated from that, and spanned by closed trefoil arches and crowned by gables flanked by pinnacles.

Triangle of the gable.

Passage on the triangle of the gable.

What now concerns the form of the elevation of the triangle proper of the gable, the proportion of the latter to the lower wall portion, it stands in the most intimate connection with the varied arrangement of the edge of the roof or of the gutters along the eaves. If then the water at the long sider simply drops over the edge of the cornice, or if generally at the base of the roof no balustrade is found, there is also no need for arranging it before the gable, since it no longer has to form a communication. Therefore the plain wall of the gable triangle is opened in any manner or is entirely closed and stands above the face of the lower wall as in Figs. 934, 935.

Now compare the first Fig. with its section in Fig. 934 a, t then the entire thickness of the dividing arch remains up to t the window wall beneath the roof, without any appearance in the development of the elevation. Utilization of it is generally n near to a simpler form of cross section of the full thickness of the gable wall, and may first consist in the use of the triforium in the gable triangle.

Thus are found in the south transept gable of the collegiate church at Wetzlar (Fig. 936) a series of piers over the proper window wall, and above them in Fig. 8 4 is visible internal piers and the closed gable wall, from which are laid thick stone blocks to those piers, that afford important support for three pointed tunnel vaults turned from pier to pier, so that the latter cover the passage between piers and the gable wall. Other examples of the same kind, which however acquire greater richness by the little columns dividing the span of the arch are

shown by the transept gables of the cathedral at Limburg, and a particularly graceful arrangement of this passage of the west gable enclosed by great towers on the same work (Fig. 937). The same motive is then shown in a way more nearly allied to the gable of Wetzlar by the transept gables of the cathedrals at Meissen and Magdeburg and by S. Blasien in Mühlhausen. Here those widely spaced strong piers are replaced by a crowded arrangement of mullions without capitals, which again follow the direction of the gable and are connected by trefoil tunnel vaults, so that their springings extend to the back wall. There the himher mullions are joined with the back wall by stone blocks parallel to those spacings. Retaining the same arrangement, perhaps the mullions could be replaced by little columns with better effects, whose capitals form that connection.

If in the manner frequently explained we now assume that the mullions or little columns are only connected by cross arches instead of tunnel vaults, there results the need of covering the passage by stone slabs, that are laid from the arcade wall thus formed to the solid gable wall. With an arrangement of the arches following the inclination of the gable, these slabs must be laid on each other with their tops forming a stairs leading up from both sides to the apex of the gable, that will later f find a fuller explanation (See Gables).

Horizontal termination of the passage.

Meanwhile the parallelism of these arcades to the inclination of the gable is nowise a necessity. Instead of this can occur an equal height of the arcade horizontally, and the passage be either covered, or instead of the stairs can be formed a second uncovered connecting passage between the corner towers flanking the gable. Then the entire construction, i. e., the arcade wall may either receive less height with the connecting passage over it, so that the upper part of the triangle of the gable rises above it, or it may occupy the entire height of the gable and thus form a horizontal termination of the west front. the last is found on the west end of the collegiate church of Mantes ((Figs. 939, 939 b) and on the cathedral of Paris, on the latter indeed being developed from the peculiar construction, so that over the two western bays between the beams is found a terrace, while the gable proper is set back to the eastern face of the towers, whose western sides are then connected by doubled arca-

arcades, that bear the connecting passage.

But we return to the ordinary arrangement, where the roof of the middle aisle extends between the towers, and thus the gable walls either extend up behind the arcade, or they retain theeir triangular form and then correspond to the front only by short columns set allording to the inclination of the gable which support the difference between the gable triangle and the rectangle formed in the elevation by the front arcade leveling the floor slabs of the upper connecting passage. An example of such an arrangement is shown by the west end of the collegiate church in Mantes (Fig. 939). We call attention here to this, that the front columns are connected with the back wall by large stone blocks, whose front ends form the capitals of the lower columns. On the west end of the cathedral in Laon is found then the peculiar arrangement, that the gable or rather the roof of the middle aisle apparently projects through the connecting passage between the corner towers, so that the entirely closed front wall only animated by blind arches of the latter appear as if placed on the gable triangle, as we have stated above for the rear wall.

Free passage before the gable. Round windows in the gable triangle.

Simpler becomes the entire arrangement by an uncovered gallery at the height of the base of the gable, whereby the gable triangle is entirely visible, and can be opened by windows at different heights. Certainly here is indicated the wheel or round window as soon as a richer treatment is concerned. Also the same which the transept of Notre Dame in Paris shows is very compatible with the arrangement of a great wheel window lighting the transept below, and even by the necessary smaller dimensions of the resulting simpler design is adapted to emphasize the size and magnificence of the lower one. The harmonious effect of the gable triangle can then be enhanced by the addition of three small and likewise round, trefoil or ordinary pointed windows in the three angles of the gable. The same purpose of a complete harmony of the opening with the form of the gable is further attained by three round windows set in a triangle, that approximate the effect of a trefoil. Such an arrangement is found on the north transept of the church of Gelnhausen, indeed at a different place below the gable in the circle of the side arch.

The design of such round windows is very compatible with that

of an arcade passage before the gable wall, indeed it is effective by the connection with the latter in a manner like the back wall of the triforium but is more effective. In Mantes (Fig. 9,9) the gable wall at each space of the arcade is opened by a little round window.

Decoration by figures in the gable.

If the arcade passage does not extend up to the height of the ridge, then a part of the gable triangle remains visible over it, and the latter can either be opened by a window or have a representation of a figure in the round under a canopy or be adorned by a relief. The last is found employed on the entire gable of S. Martin in Laon.

A very peculiar development is shown by the west gable of the church at Pforta. For here before the proper stepped gable of the church is corbelled out an arch occupying nearly the entire width, which terminates at top in a simple gable lying before the stepped gable, and thus forms a colossal canopy, beneath which is represented in the round the crucifix, with S. Martin, S. John and 4 angles beside them.

But the most beautiful and perhaps in this way unique example of such a filling of the gable is presented by the Liebfrauen church in Treves, whose gable does not occupy the entire breadth of the roof, so that under the gable triangle is inserted a rectangle. This entire area enclosed by an inclined cornice filled by leaves is then divided into three blind arches, which are s simple round arches. Before the middle one is placed a closed crucifix, while S. Maria andS. John stand in the side arches.

Pointed windows in the gable triangle.

As in the window stories of the west fronts, also in this triangle the wheel window is commonly replaced by a pointed window, indeed either being filled by great dividing mullionswith tracery, or by several single windows placed beside each other. T The latter may be of equal height, or increase toward the middle, so that the entire group approximates the inclination of the g gable or is parallel to it. With uniform heights, above the window group may be found a second and again concentric opening.

Resolution of the gable into tracery gables or steps.

On later works the entire area of the gable is divided by piers with pinnacles into a number of spaces usually divided by pilasters and connected by arches, that again end in gables at

top, which extend between these pilasters.

By such an arrangement is found as the earliest and best example on the church of S. Elisabeth in Marburg, the triangular f form indeed passes into the stepped, and is but partly visible through the openings of the arcades. Thus eo Marburg the general arrangement still has great freedom, far removed from the almost rigid effect of the later development with pinnacles.

For the width of the gable is divided in three pointed blind arches by mullions and tracery, the middle one far exceeding the others and occupied by a rectangular doorway almost to the base of the arch, from whose lintel are corbelled out the pilasters dividing the upper part of the blind arches. At about the same height are corbelled from the intermediate and wall piers 4 pinnacles in the form of Equilateral triangles, between which gables span the side recesses, whose openings end at the same height as those of the finials. Directly over the latter are corbelled out before the intermediate piers again two entirely similar pinnacles, between which a gable spans the middle recess. At the height of the corbelling of the last mentioned pinnacle are then found a horizontal cornice over the side gables, on w which are then set 3 little turrets, the middle one of them standing over the crowning gable, and between which the horizontal line of the cornice is animated by two half battlements adjoining the turrets and a giddle stepped one.

If this gable is in the most beautiful harmony with the west window beneath, that belongs to about the close of the 13 th or the beginning of the 14 th centories, like the Elisabeth church in particular, somewhat forestalls the contemporary development of other works, and it must be difficult to find a suitable termination for the latter, then the other examples of this kind in Nuremburg, Prague, etc., are merely variations of the same theme, that first differ from the Marburg example by more subdivision and then also with the gables of the separate steps continue horizontally above the surface of the gable between the separate pilasters, and divide them into several stories.

If on the gables of the transepts and of the west end the passage beneath the windows of the window story is arranged the same as on the longer side after the manner of Fig. 913, then for the upper one at the height of the base of the roof is eith-

either isolated, or the area is lost for the passage connecting the roof galleries. This evin the case on the longitudinal walls, yet here is easily obtained the necessary area to receive the roof beams bu an arch turned inside the face of the wall above the springing of the compartment and resting on the thickness of the vault. This becomes more difficult to execute on the t transepts on account of a length of bay far exceeding its width, and thus it is nearer to avoid that loss of area, so that the upper passage comes to lie exactly over the lower one, and is supported by any construction resting on the latter. Such an example from the Strasburg minster has already been mentioned on p. 351. Other arrangements would consist of an arcade set on t the edge of the lower passage or of an arch turned between the buttresses. If we conceive the latter applied on the transepts of Chalons, (Fig. 9 .), which in reality terminate with a hip roof, then would the arch concerned be about concentric with the upper pointed arch. In contrast to the before mentioned arrangement the gallery on the south transept gable at Colmar would be simply supported by strongly projecting corbels.

To all the richer forms mentioned we again compare the very simple gables of Notre Dame and of S. Leger at Soissons, as proof that with entirely consestent execution of the whole, and the almost necessarily resulting good proportions that richer ornament was not at all required to produce a happy effect.

Inclination of roof and gable.

But of great importance is the proportion of the inclination of the clearstory roof. If it is not to be denied, that the G Gothic art of the last period was especially pleased by the arrangement of very steep roofs, and likewise conversely was so fixed, that this nowise excludes the design of flatter roofs, as such are presented by the frequently mentioned terraces, and usually low roofs of the side aisles, and also the roofs of secular buildings in southern countries, and even the houses of Swiss and Tyrolese peasants, still in general the preference is for steeper roofs particularly for covering church buildings. As limits for the inclination of clearstory roofs may be regarded the proportions of 5/7 to 1/4. But also an increase in parts carried higher, those of the clearstory roof above that of the side aisles, of the tower roof above the former results almost necessarily from the verticalism peculiar to Gothic art. For

example let Fig. 938 a be the outline of a choir with clearstory and a tower at one side, which is constructed according to the principle just mentioned and thus is easily attained its stately height, while in Fig. 938 that formed with parallel inclination is lamentably inferior; yet in reality this contrast is more decided according to the laws of perspective. Also to the horizontal termination is peculiar an equal division, particularly if certain higher parts of it exist, while the flatter inclinations of the roofs, especially in great groups of structures, produce the effect of stumpy indecision, and also require with a simpler design certain decorative or structural additions, in order to conquer this, as to be sought in the great acroterias of the Greeks and the wide projections of the roofs of those mountain houses, to which we have just referred.

Further reasons resulting from the propor purpose of the roof and of the nature of the materials to be employed, particularly in our climates, we leave entirely aside as generally known, and we state only that particularly in the restoration of mediaeval works the preservation of the original inclination of the roof is the more important, when it seems to oppose too much the modern esthetic feeling at least in many places, so that in the p present time many roofs of old churches require earnest help, for the danger is near, to see them replaced by designs of roofs suited to the so-called spirit of the times.

But may all capable of such a beginning previously subject t those examples to a more careful examination, in which the mentioned change of the roofs is shown completed, and the effectiveness of the outline thereby obtained be compared with that, which the work produced in its original form as in Merian's Topography, the trivial proposed form with the bold decidedness of the old; we believe that it would be rejected. (Illegible).

VI. SUBDIVISION AND CROWNING OF THE WALL.

1. Subdivision in General.

The continued subdivision of every kind in cornices, jambs, enclosures, piers, etc., is composed of the following elements.

1. Plane surfaces (slabs, chamfers, bevels, washes).
2. Projecting curved surfaces (rounds, scrolls).
3. Sunken curved surfaces (hollows).

Separate mouldings.

Each of these surfaces may already by itself form a moulding, and thus a simple round may serve as a neck moulding of a capital, and a simple chamfer, a rounding or cove, as a decoration of an angle. But usually several surfaces are joined together in a moulding, either forming a gradual transition or a simple combination side by side.

Compound single mouldings with gradual transition arise, when plane or curved surfaces so succeed each other, that in the cross section the separate parts of the profile adjoin each other without breaks (with a common tangent), and there are formed in this way transitions from the cove to the plane (Fig. 940), from a round to a plane (Fig. 941), from a cove to a round (Fig. 942). Transitions from a curve to a larger or smaller one in the same direction (Fig. 943) can scarcely be counted among compound mouldings, when they do not represent in the cross section a succession of circular arcs (Fig. 943), but a constant change in curvatwre (ellipse, parabola, spiral, etc.); mouldinms of the last kind are usually drawn freehand, and therefore cannot be represented or named mathematically.

Compound single mouldings with abrupt transitions occur, if flat or curved surfaces with expressed angles so adjoin each other, that they always produce the impression of a single member. To these belong the compound bowtell (Figs. 944, 945), intersections of pointed rounds (Fig. 946), even mouldings with divisions like a bundle of rounds (Fig. 947) or a fluted round can be included here. Thise forms already lead to placing mouldings side by side, the proper members.

Combined mouldings.

Rich members are combinations of single mouldings of more or less value connected together, or by small intermediate small mouldings. Hence the projecting mouldings are generally termed principal, and sunken ones are intermediate.

According to the succession and direction of the connections, the predominance of one or another moulding, the course of the lines in each separate moulding gives an inexhaustible abundance of expressions of form, which in every style speak a particular language without the addition of other ornament. The stage of the culture of the people, its entire mode of feeling, surrounding nature, climate, existing structural materials, and many other effective circumstances contribute their influences in the development of every architectural member. How greatly the same profile of a member may change its expression may be represented by the comparison of a crowning member (Figs. 948 a, b,c) and a base member (Figs. 949 a, b, c) in antique, Romanesque and Gothic conceptions.

Already in the separate divisions of Grecian and Roman art was completed a transformation of the members, which even more decidedly continued in Byzantine and Early Christian art, so that the so-called Romanesque style exhibits a new stamp.

Romanesque members.

Romanesque members avoid soft transitions, but place the separate mouldings directly or by mean and small connecting mouldings without expression beside each other. The curves are near circular arcs, the expression of the mouldings is plain and modest, rounds and coves exhibit a moderate extent of one fourth to one half the circle.

Gothic members.

To Gothic members are peculiar great life and heightened expression. Transitions are according to needs, sometimes soft and sometimes very decided, rounds and hollows predominate, and where bold effects are concerned the semicircle is important, but on the other hand also occur very delicate curves. The simple circular arc becomes rarer, freehand curves dominate, that show constantly changing curves like the style of spiral lines, they are found beautifully expressed on the lower torus of the base, the concave line of the capital, the cavetto of the main cornice, and they are very particularly suited to exhibit the noble inventions of the master. The effect in place is always studied w with great devotion, it leads frequently to a course of the lines, whose appearance is almost foreign to geometrical drawing, while in reality it exerts a very particular charm.

In the members of the external cornice occurs the necessity

for safely conducting away the falling water, expressing in this its rights, of washes thereby required assuming a particular expression and iyfluencing farther the form of the cornice. Similar washes also occur at many places in the interior, where it is necessary to avoid concealing the wash from a low position of the observer.

Diversity in the development of Gothic mouldings is almost unlimited, it goes so far that even mouldings corresponding to e each other in the same building always exhibit new changes according to the relation of the different parts, the height of t their location, the standpoint of the observer, the lighting, etc. Otherwise their generally strong variations not only accord with the art divisions of the different times, but also according to the lacally different activities in art. In the last respect is expressed very particularly the material at command in the vicinity. Entirely aside from the separate forms of brick and wood construction, cut stone shows very great peculiarities according to its softness, cleavage, color, dimensions of blocks, its grain and polish, that find their reflection in working and in the appearance of members. The middle ages never did violence to building materials in its best epochs, but utilized and treated them as they deserved..

Formation od mouldings in brick construction.

Brick architecture is far different from cut stone architecture in its innate nature and external expression; in the middle ages it ever took its even course, so that one can speak of a separate brick style. Its differences lead in part to the peculiarities of artifitial stone, but rather refer to its mode of preparation. Forming and burning supply only small pieces of uniform size, that for the great mass of masonry receive a simple prismatic form. With these ordinary wall bricks are even constructed simple cornices peculiar to brickwork; yet when members require moulded bricks, whose kinds are limited as much as possible in the same structure, when the same brick finds use so far as may be in different places. The moulded brick as a rule is restricted to the dimensions of the ordinary brick, it is made in special moulds or prepared from the usual bricks by cutting off the superfluous clay, and sharp reentrant angles a are to be avoided. Developed forms like moulded angles and yet more plant and figure ornamentation must be shaped by special

moulds or by freehand modeling.

There prevails in brick architecture in a certain sense the industrial character over the artistic .nd fanciful, that is peculiar to stone architecture, but sound logic expressed in all its members as in the arrangement of the whole, causes it to be scarcely inferior to that in respect to style.

While until in the 13 th century a tendency toward stone forms is made known, thereafter the members of supports, arches, jambs and cornices ever become more independent. Among others the main cornices do not adopt the great cavettos of stone structures, they are animated by arched friezes or arrangements of moulded allied to these, by continuous terra cotta plaques or recessed panels of plaster. Drip mouldings or undercuts are restricted to the height of a course set on edge or a roll (Figs. 950, 950 a) and do not fail at the projecting edge of the roof. A drip could even be formed by the lower projection of a simple inclined brick as shown by the window sill of Fig. 951, where p is the covering brick course and a would be the lower piece of the window frame.

For a brick moulding to be effective, it must have a certain least dimension, in order to appear above the strong color of the wall, as well as the contrast of it with the white joints and the usually alternating glazed courses. Thus generally and aside from the technical execution, the size of the moulding depends on the material, its color and texture. Thus as we see on Grecian temples the fine grain and color of marble permitted more delicate members, than dark and coarse grained sandstone or limestone, hence it is more possible to design members in t the mass more gracefully, when the different parts are separated by different coloring, as again on the Grecian temple and on mediaeval woodwork. But every puerile and weak member in brick is ineffective in a high degree, as so many modern brick buildings prove.

An exception in regard to the size of mouldings is formed by the ornamental bands occurring on the richer works, as on the architrave of the Holstein gate at Lübeck, which consists of large peculiarly shaped and glazed plaques forming rich tracery or foliage ornaments, whose lines then show sharp members, thneither great nor deep. Since here the operation of burning demands a great difference in the thickness of plaques, as would

have been unavoidable for deep mouldings, then were rather less necessary, rince these ornamental bands already by the continuity of their color are separated from the otherwise colored wall surface in coursed patterns, thus their members are in relation to the size of the plakues rather than to the whole.

But this combination of the members by color is thereby obtained on most north German brick monuments also on window and doorway architraves, since these are set with glazed bricks, w which then contrast with the red or striped wall color. It is understood that the use of glazed bricks at angles and jambs was first allowed by the need of giving a protecting coating to the most exposed parts. Figs. 953 and 959 exhibit different moulded bricks chiefly taken from works in Lübeck, that either are derived from the chamfer, like those in Figs. 956, 957, 959 a, b, c, or from the round shown in Fig. 952. The peculiar form of Fig. 954 is generally executed in elevation in the way that the separate lines a, b, c, are spirally cut in the thickness of the brick, so that a comes at b on the bottom surface, etc., as Fig. 954 a shows. Care is to be taken for such mouldings, t that the extreme edge at d in Figs. 954 and 955 are not too weak but remain at least 3 cm.

For each combination of the separate moulded bricks in a richer member the wall bond is then determinative, which allows the form of the entire moulding to appear with a certain number of rectangular angles of the width of bricks or half lengths as m most natural, like a d b c in Fig. 959. This ground form may t then receive the simplest modifications, if the separate moulded bricks are separated in places by flat surfaces set between them of about half a brick wide, so that the series of bricks result as a e c, a e f or g e c etc.

All separate mouldings represented hitherto are symmetrical with the diagonal, so that these bricks serve as stretchers or headers. More varied forms are obtained when this symmetrical shape of moulded bricks is dropped, as shown by Fig. 958. But the shape of the separate bricks so far depends on the bond, that the centre of the hollow lies about in the prolongation of the end joint, so that the end joints pass at right angles through the moulding. Fig. 960 represents the bond of such a jamb, and shows that to execute the same, the length of the bricks must be to the unchanged widths as 3 : 2, so as to reg-

require the so-called three-quarter bats.

But this length no longer suffices for a jamb profile formed as in Fig. 958, since then as the line b c shows, the strength of the brick at c remains much too small. Therefore to make the bond possible in the same condition it is necessary to transfer the joint b c to d e, so that the length of the brick is to the width as 5 : 2.

A rich selection of such brick jambs is contained in the works of Essenwein, Adler, etc.

Mouldings of woodwork.

By the lengths of the timbers supplied by nature, by the direction of the fibres, a difference in strength connected with them crosswise and lengthwise, further by the sensible hygroscopic peculiarities are the ways indicated for treating woodwork. Structural members were so closely adapted to the peculiarities of the material and the purpose of the object in the middle ages as in no other division of art. Likewise the purely ornamental members have their character expressed in wood construction. Here and there indeed a certain echo of stonework is not to be denied, but then there is always a transformation corresponding to the purpose as to the material in like manner.

But an objection to this relation of forms for mediaeval art is unfounded, at least for those which cannot find words enough to wonder at Grecian art. If then one still in modern times (in spite of Semper, Durm and others) cannot exclude the duration of the assumption that many, and just the more essential parts of the Doric order are merely memories of a prehistoric wooden architecture, that men endeavored to transfer the forms peculiar to the lighter and tractable material to the heavier and more stubborn stone, even such forms as were meaningless for the latter construction, like drops and mutules. But it was far nearer then for mediaeval workmen permeated, as they must have been, by the nobility of Gothic art first belonging to stonework, that they strove to make a part of the fullness and magnificence of it peculiar to their own handiwork. They indeed transferred just in a concise sense the forms of the unyielding to the more yielding, material, and indeed not blindly imitated but transformed them.

This change from stone to wooden forms resulted from natural conditions. At first in the various works in wood it did not come to produce monumental effects, but to serve the purposes of the

lives of citizens, or in works rather belonging to furniture to obtain a certain convenience for use. Thus works of wooden architecture are almost entirely found near the eye, thus permitting a greater refinement of grace in the forms, to whose aid almost always came painting, which could occur only in a far more limited way on stone architecture. But the material itself aids this greater detailing, so far as it allows sharper angles, use of thinner masses, conditions of the connection of different parts, the requirements of stability reached by lighter and simpler means, and thus favored a freer and more ornate treatment of the whole. As in stone construction all undercut members in the interior are more or less lacking a technical purpose, and where they occur only the bold effect is retained, so in the woodwork vanish all requirements to be necessary, since even in external architecture the desired protection is of brief duration because of the transitory nature of wood when exposed to dampness. Therefore where on woodwork are found forms, that seem allied to the cornices and mouldings of stone construction, they serve there only as crowning and ornamental bands and thus a m merely decorative purpose. Hence in but few cases are they wrought in the solid mass of the wood, but far more commonly are n nailed on. Accordingly from the almost typical stone profile in Fig. 9 1 are formed the wood profiles in Figs. 962 and 963. If these are nailed on, the deepest part of them must not be on the face of the wall (as in Fig. 961), thus here falling on the line a b, but at c must remain sufficient wood that the nail holds the strip.

The sharper and thinner form of the edges and of the projecting parts further makes undercutting for the effect dispensable. But in certain cases it makes more difficult the work in quite a superfluous way. For example where such an ornamental band forms an angle at the edge of a frame, it is returned on itself (Fig. 964), the joint is not mitred according to the term, and modern practice is given by the thin line a b in Fig. 964 a, but is cut rectangular according to c b in Fig. 964 a. The first position of the joint will exhibit that ugly separation of two parts (c a b and d a b), that is so unpleasing in woodwork by the least drying of the wood. If then no intersections are found in the moulding of the crowning band, then each piece can be s stuck and then the moulding be coped for the distance a c at the

angle in Fig. 964. But if the cavetto is undercut the piece e f in Fig. 964 cut out of the fillet and must then be glued on again, if the angles op the band were merely stuck beforehand, hence producing an otherwise superfluous difficulty in the work.

Every sharply cut edge, that is so easily produced in working wood, is quite objectionable at all places usually exposed to human contact, since on the one hand the contact is unpleasant, and on the other it is easily lost thereby. Therefore on all such parts like architraves of doors and windows, framing and panels, etc., occur members for removing the sjuare angle are to be considered, such as chamfers. Their forms mostly suffer important modifications as a rule by the small thickness of such frames, that makes it desirable to increase the proportion of the width of the member to its depth. Accordingly the forms of Figs. 965 and 965 a become almost typical, by which are then also found other combinations, such as shown in Figs. 966 and 966 a. In a similar way mouldings are placed flat beside each other on wooden verticals, in order to form a slight projection of the upper and lower parts (Fig. 967). for more on this see p. 233.

More boldly shaped mouldings are usually found on ends of beams, that bear the projections of upper stories. As a rule t these approach the rectangular form (like Fig. 9.8), since then generally the shape of the profile must be such, that the strength of the loaded end of the beam is reduced no more than safety permits. Examples of thes kind are shown by Figs. 969, 970.

The members of the sill lying on the ends of the beams, that become square at their bearing on the latter, also mostly correspond to mouldings suited for stone. Here may again occur undercutting, which will indeed even be useful so far as they prevent water from running down on the filling boards. But generally these are not moulded but retain the rectangular cross section like the antique architrave, and only their front side is covered by a surface ornament of tracery or foliage. More rarely are also mouldings nailed on outside, like railings of balustrades, whose forms may be about as Fig. 963, or better be a simplification of these. Purely ornamental are then the mouldings sometimes stuck on verticals and rails, that remain entirely in the plane and thus form no projection, being made with the steel in the wood as a substitute for a mouldinm in actual relief. S

Such a form is shown in Fig. 971.

Mouldings in metal.

While cast metal allows the greatest freedom, so that it lends itself to the representation of almost all forms that can be executed in other materials, wrought metal and especially forged iron draws the limits more closely. Mouldings, such as occur in stone and wood, almost wholly disappear in wrought iron, and men labored to replace the decorative effect by other forms more s suited to the nature of the material, or the lines forming the edges of the moulding were given, which in a drawing received only slight sinkings. Most commonly are found members on those iron parts that seem imitated from the buttresses of stonework, and therefore bear the same mouldings as those. For example such posts are found in iron grilles that enclose tabernacles, fountains, etc., or even form closures of choirs. The bases of these posts as a rule are then very simple, only having a chamfer or the moulding given in Fig. 972, on the contrary the cap is sharply cut with a thin border, formed about as in Fig. 973. The latter form is also sometimes assumed by continuous rails, as on the beautiful grilles of Magdeburg cathedral, on whose posts are also found more complex forms (Fig. 974).

On the imperforate tracery sometimes found is usually made a member of it in this way, that two thin hammered perforated bars are placed on each other, the lower projecting beyond the upper, so that Fig. 975 forms a cross section of a bar of the tracery.

Richer mouldings are found on bronze works, by which men in the middle ages usually strove to excel the magnificence of s stone architecture. Examples of this kind are presented by the bronze baptismal fonts of Würzburg, Münden, Einbeck and Lübeck, the lead fountain at Brunswick, and the extremely rich tabernacle of the church S. Maria at Lübeck. On all these works is found cast metal combined with forged work, as shown by the inscription on the latter. But by this procedure it was possible to attain the freedom of separate forms and the gracefulness of the moulding, which these works possess above similar modern works, especially those of highly prized cast iron. Fig. 976 shows the rail and base of the lower balustrade of that tabernacle, and Fig. 977 is the base of an upper pier (Note).

Note. See the Gothic Musterbuch of V. Statz and G. Ungewitter.

In the later periods of Gothic art, men sometimes toiled to

transfer also to stonework this delicacy and refinement of metalwork, when they made the hollows wider, projecting mouldings thinner and replaced rounds by angular mouldings. The greatest excesses in this respect are found in the French works in Late Gothic. As an example with all this thinness yet with a very effective cornice member from the palace of justice in Rouen may serve Fig. 978.

Still more graceful than the bronze works are those executed in noble metals, even if here the necessary handling opposed all sharp angular forms. But the genius in the mediaeval work which compares with modern, about as a sketch executed by a sure hand to a careful geometrical drawing, they also knew how to obtain in this case. Thus is found on the most graceful mouldings of this period, as for example that given in Fig. 979 from a monstrance in Hildesheim, yet avoiding all injurious sharpness.

Preparation and execution of the members.

Preparation of the mouldings.

It lies outside the scope of these pages to follow the manual execution of mouldings into their details according to materials.

In stone it is done according to the profile laid on the dressed plane surface, that for vertical mouldings corresponds to the bed joint, or for horizontal ones to the end joint. Execution is done with the template, which then after the moulding is cut must pass along the cut out space.

For bricks it is made by a mould in which the unburnt brick is pressed, or with a plane that cuts out the sinkings.

In wood it is effected by the plane that corresponds to the template, and where this does not suffice or is inconvenient, by chisels and gouges of different shapes, which are also employed as aids to the plane.

In cast metal it occurs with the pattern, and only in forging with freehand chiseling; in brief on all these works, only excepting the last, in the same manner in which the elevation is made from the plan or elevation in drawing.

Where a moulding extends around a corner, the line formed by this is executed by cutting at the same time, for wood sometimes by Mitring. In the same manner are found in practice the lines of all penetrations, both of the same as of different mouldings.

Projection of members.

In the earlier original sketches preserved to us are not found

such projectinss. Men in a sense drew as they worked, just as writing was formed from speech. Every projection on an inclined surface was avoided, and as on the original sketches of the Cologne towers, the architecture on the inclined octagonal sides was drawn exactly as if vertical, so that then on account of the defective width of the former, they were represented as cut off. Only occasionally were men assisted by an entirely conventional perspective. Yet at present it is no more expedient to employ such an artless mode of representation, we are already by custom so bound to a strict execution of projection, although this has little value in practice for oblique surfaces, since only in heights is given the actual measures. From the danger of repeating something long known, we shall explain the graphical representation of the intersection of members in certain frequently cases reduced to the simplest forms.

Examples of execution.

1. A moulding (a in Fig. 980) extends horizontally around a square corner. In the elevation the correct profile is shown at the angle b, where the intersections are not visible, yet on account of clearness they are indicated by dotted lines. But in the projection on a plane inclined at 45° is then shown the actual line of intersection of the moulding over the ground line c d in Fig. 980 a. This line must also appear if the body on which the moulding exists is placed like a square set diagonally.

To draw it, the points c e f g d are projected perpendicular to the base line c d above the line h_1 y_1, above which will be represented the profile sought . On these lines from h i are laid off the heights of the points determining the profile, which are lettered the same at a (in Fig. 980), so that also the heights of the points e′f′l′g′a′from h i are equal to those of the points e f l g d from c k; thusethe main points of the profile are found, that can be drawn so far as composed of straight lines. For determining the curves more points must still be found, at least m in a determining the lowest depth. The height of the latter from the line c n is therefore laid off from o to p, and the line p p is then drawn to c d, and from there the point p above h i, laying off the height of the point m from c k on the last line from h i, finding the point m′. In the same way are other points to be found from an accurate determination.

2. A moulding extends horizontally around an obtuse-angled c

corner (Figs. 981, 981 a). The relation of the points b c d e f to the corresponding points of the profile drawn in elevation is given by the similarity of the letters, so that the distances of the lines on the plan from b b′ are equal to those of the points of the profile from b h.

The points of intersection of these lines with the line b′f′ bisecting the angle are drawn upward in the elevation with the heights of the lines above, etc., so that the determining points of the line b′f′ are obtained. For a more accurate determination of the curves one proceeds as indicated in Fig. 980 and shown here by the dotted lines g g′ and q q′. But it is at least necessary to find those points which form the greatest heights and depths of the profile, like the point m in Fig. 980 and here the point g, so that if the line of the hollow or round is struck with compasses, the point of intersection of these with the horizontal and vertical radii, or if the intersection is not g given, the intersections of the profile with the line through the lowest point od the overhanging edge of the profile, i.e., the point i.

3. A moulding or a body with a simple ground form intersects an oblique plane like a wash (Figs. 982, 982 a, b). In this case the position of each desired point of the plan in the elevation is obtained in the following manner.

There is drawn from the plan, as from the point e, a perpendicular in the elevation (Fig. 982 a), laying off thereon the distance of this point from the edge of the wash in the section, thus the length f e in plan in the section of the wash (Fig 982 b) from cW and e′, erecting a fperpendicular at e′, and from the intersection of the latter with the line of the wash is drawn a horizontal, that cuts the vertical first drawn from c in plan, thereby determining the position of the point e″ in elevation. In the same way are found all others, as indicated by the similarity of the letters and the dotted lines. It is now only to be noted, that the distances of the points sought from the edge of the wash must always be taken in the half of the latter inclined at an angle of 45° to the plane of projection, and always in the direction perpendicular to the wash, so that also to find the position of the point p, the length p j must be laid off in the section from c′ to p′. The section of the wash is drawn twice in Fig. 982 b, so as not to mix the aiding lines.

4. - pier of polygonal section stands on a wash of a different polygonal form, i.e., a prism intersects a pyramid (Figs. 983, 983 a). In Fig. 983 a b c d gives the plan of the pier and e f g is that of the base, from which the wash rises.

First the angle points of both polygons are brought into the elevation, thus those of the base below and those of the pier above the line h h indicating the edge of the wash; then draw horizontally the line i, whose distance from h indicates the height of the wash, then upward through the points a k d, that denote the middles of the octagonal sides of the pier, so that the intersections of this line l l' give the points of intersection of the wash with the sides of the octagon, and the edges l l' are determined. Then draw from b in the plan a line parallel to e f to the line e a, and erect a vertical on the elevation from the intersection m, which cuts the line l l' in n, and then a horizontal from n, the intersections of the latter with the edges of the octagonal pier are the points at which these edges rest on the wash. Connecting these with the points l already found completes the construction.

The same transition from one ground form to another may also be made in the manner given in Fig. 983 b, and thus according to any ground form. The graphical representation is similar in all cases.

5. Two differently shaped members, one of which is horizontal and the other vertical intersect each other. Such cases occur when the members of a doorway jamb stop on a moulded base, or if in a larger blind arch is a doorway covered by a straight l lintel, so that the members of the lintel intersect the members of the jamb of the arch, or when in an ordinary window with a stone cross, the horizontal transom bar instead of having the section of the muntin is formed with an ordinary drip moulding, etc. The first of the cases mentioned will suffice to explain the method.

Let Fig. 984 a be the plan of the members of the jamb, Fig. 984 b be the profile of the base, which in Fig. 984 a extends around the obtuse corner. It is first to draw the lines formed by both profiles in plan and elevation, and thus to select those points that determine the lines of intersection. Such points are those in which the edges or bordering lines of the separate members that strike the profile of the base, on in which the edges

or bordering lines of the base cut the profile of the jamb, or with recurved members, those in which the curves intersect.

Points of the first kind are k d l h in Fig. 984 a; points of the second kind being c m i b. To these are added those required for more exact determination of the curves, like f g in Fig. 984 a. To determine the point d, draw a d in the section in Fig. 984 b from a″ to d′, erect at d″ a perpendicular, and through the point where this line cuts the line of the profile of the base, draw a horizontal in the elevation at the same height (Fig. 984), and then the intersection of this also with the horizontal in Fig. 984 designated by d′, with the vertical through the point g in the plan will be the point sought.

Likewise to determine the point h, whose rectangular distance from the line a a in plan, in the section from a′ to h′ reaches in h′ a vertical that cuts the profile of the base three times. These intersections are drawn in the elevation, and thus the intersections of the last lines with the verticals through h are the required points h′, h′, h′ in Fig. 984. The point i or a c corresponding one results in the elevation from the intarsection of the edge line concerned of the profile of the base with the perpendicular drawn through i in Fig. 984 a according to Fig. 984. But since the round in the profile of the base has received greater projection by horizontal additions, then the lines 6 and 7 in the elevation are not identical with the line 1 in the plan, but the plan line corresponding to the first is set back farther, indeed so that this distance from the plan line a a is determined by the distance of the centre x of the round concerned in the section from the line a′a″. Therefore this distance is laid off in the plan, and accordingly there is drawn the dotted line 10, which strikes the profile of the jamb in o o o, these points are drawn in the elevation, and thus the intersections of these lines with the border lines of the round give the points sought at o′o″, by which the beginnings of the curves are determined, in which the round intersects the separate parts of the profile of the jamb. To determine the extreme point of this curve, or the point m, draw from m a vertical to the elevation and from the centre x of the round a horizontal across to it, so that the intersection of both lines gives the point sought.

2. Cornices.

Principal cornices.

Romanesque main cornices.

In countries where Romanesque traditions remained active, the cornices of the Romanesque style sometimes showed a great mass of corbelled members, but in general the principal cornice as well as the belt cornices at this time had already assumed a s simple and clear expression. There predominates either the round or the cavetto (Figs. 985, 986), or the round and cove succeed each other in rhythmic sequence. The clearest and most expressive succession of mouldings to be obtained in the last way, must be the combination of two roundu with a middle cove (Fig. 987), and it has also been employed in manifold variations.

It is preferred to term the last moulding an inverted Attic base. Although a course of development from the Attic to the mediaeval base may be followed, the assumption of inserting this member for a crowning one is somewhat strong, and as we think is also entirely unnecessary. If usually there was an endeavor to place round and cove beside each other, which Romanesque art has done in every possible sequence, it was so self evident, that one must hit on this form, indeed on account of its near simplicity in the first line, that to explain its origin does not require the traditions of the Attic base at all, so t that at most a certain facility in its use could be derived therefrom.

Those simple mouldings as shown by Figs. 985 to 987 are not sufficiently important for prominent belts or main cornices, e even if ornamented, and therefore subordinate members are usually added, that consist of continuous slabs or bands lying in t the surface of the wall, a frieze interrupted by small piers ((Rhenish works), and corbels (especially in Burgundy) or the a arched frieze employed on German works with such preference.

The manifold treatment of the Romanesque cornice transfers itself to Gothic, in the lower members particularly developed in brick Gothic, while the art of cut stone rather returns to the upper continuous members and especially to the cavetto beneath filled with foliage in predominant places.

Gothic principal cornices.

Like everw other cornice, the principal cornice must prevent water from running down the face of the wall beneath it. Already the under surfaces of the Greek cornice in reference to this technical requirement is either obliquely undercut, as in the

Doric order (Fig. 988) or has a water drip as in the Ionic (Fig. 989). But to Gothic art was it reserved to devise an art form and from the fulfilment of this purpose (Fig. 990). How much t this form depended on that purpose is shown by many works executed with a certain economy, on which the undercutting or drip formed by the projecting edge of the roof covering was superfluous for the cornice, and therefore the latter consisted of only band and chamfer or band and cavetto (Fig. 991). It then had o only the function to remove the fall of the water beyond the f face of the wall. But any richer treatment would be made uncertain by the shadows of the edge of the roof, unless it was removed from their reach by a vertical surface of sufficient height, t thereby resulted hhe band a in Fig. 990 as an essential part of all such forms of roof cornice in contrast to the design of pseudo antique or modern cornices, in which generally the very d delicate upper edge is not alone concealed by the margin of the roof, but even by an inclined gutter hanging before it (on account of removal of water), and all richness is made unrecognizable. But by the vertical band a the undercut cavetto is then again moved so far downward, that the function of removing water indicated by its form can be actually fulfilled. The height of this band generally equals the projection of the cornice, thus being formed as in Fig. 992.

Cavetto with drip at edge.

The members have an endless variety (Figs. 990 to 999). The most common if not the earliest profile is shown by Fig. 992, especially the slope in which a cavetto is cut; on account of its clear and simple form it may first be mentioned. It is recommended by ease in execution, which depends on the fact, that the stonecutter has to dress the minimum surface possible, which is removed by mouldings to be wrought later. Thus the oblique surface a b is first cut, in the latter according to the size of the cavetto is made a rectangular, oblique or triangular sinking c d e or c f g e, and thus the remaining circular segments between the sides of the sinking and the line of the cavetto are removed. It is generally necessary in the design of every member to take into account the mode of execution, and to draw the profile in the same way as the stonecutter works. Thereby can be avoided most certainly the very difficult and least effective forms.

To establish a definite proportion of the chamfers a c and eb to the diameter of the cavetto is impossible. According to the nature of the stone the distance a c, that results from the thickness of the overhanging part, may increase or diminish. As the lower limit may be designated a width a h = 1/4 of the width a b. According to the material is arrangem the depth of the cavetto, and thus the choice of its centre. In no case must the cavetto extend behind the face of the wall, so that g lies behind the line b i, while this point may well lie in it. From the choice of the centre and of the radius of the cavetto also results the width of the lower chamfer e b as greater or smaller. A satisfactory proportion results if a c + e b = c e and a c is : cb abo about as 5 : 3. The edges formed by the intersection of the cavetto with the chamfer best retain the rectangular form, and any pointed form is only permissible so far as the strength and fine grain of the stone permits..

In case the point g falls in the surface of the wall, the lower part of the profile can be omitted and the cavetto pass into the vertical surface, therefore being cut in a lower stone. It may likewise rest by a horizontal cut k l on the face of the wall.

Further the transition can be made by a rounding oninstead of the chamfer b e, or by a round in richer forms, that projects from the curve of the cavetto (Fig. 992 a) or this may intersect that (Fig. 992 b). Thus also the lower chamfer can afteruards be undercut (Fig. 993), as any combination of the different methods indicated above may occur.

Varied profiles.

The upper edge may also receive a richer form, as by the addition of the two chamfers a n and o n (Fig. 992) or a chamfer and a cavetto. The chamfer a n is therefore particularly characteristic, since it typifies the indispensable water drip in all other cornices, and that as a special undercutting of the roof cornice separates the upper band from the mouldings. This simple cross section in Fig. 992 may form the outline or rough shape for the richer and nobler forms given in Figs. 993, 994, and 995. The latter are entirely taken from earlier works, and we have attempted to bring them into a geometrical scheme as indicated by the lines sketched in. Yet no very great value is to be placed on the latter, and they may serve rather merely to assist the beginner.

But a slavish adherence to any such network of lines must be injurious in any case, and they are to be used in determining only a few particular points, while the same connecting cavetto either is to be struck from a freely chosen point, or is to be drawn freehand. The last procedure doubtless preceded the geometrical determination, even when all arches were struck with the compasses from points determined by the scheme.

On the earlier works are sometimes found also the undercut outer edge separated from the member below it, so that the latter has to support the overhanging edge drip. An example is presented by the cornice of the west faced of the cathedral at Rheims (Fig. 1000).

On many profiles and particularly of Early Gothic, the undercutting is transferred from the upper edge of the band to the lower edge of the cut stone, so that there results the form shown in Fig. 996, which is distinguished by a particularly bnld effect of shadows.

Richer main cornice.

Thus in Figs. 991 and 991 a the edge of the roof projects beyond the face of the wall by means of a cove, so that also the drip forming a cove is set back by a second moulding beneath it. In the simplest case the latter imitates the former at a smaller scale (Fig. 997), or since the undercutting strictly taken is here superfluous, it receives a different form. These compound forgs of cornices are especially indicated where they consist of two or more courses lying on each other, as also in Figs. 997, so that each course has its own profile. Yet sometimes the form of the profile is independent of the location of the joint and the latter intersects the entire member with only a care for the skilful form of the edge (Fig. 999). The latter best suits the rectangular form, leaving the pointed, as dependent on the resistance of the stone and on the weight of the ashlars lying on it.

In the richer forms of cornice the ashlar with the upper undercut cavetto is generally supported by one steeper and flatter, that is entirely or partly filled by leaves. These latter have on the earlier works an actual structural importance and serve to strengthen the upper margin, Figs. 1000 and a in Fig. 1001.

But still more essential becomes the function of this over-

overhanging part of the cornice if the upper ashlar forms a gutter to receive the water flowing down from the roofs. The border of this gutter tehen has a parapet on the more richly formed c cornice in order to make access easier. The arrangement of the gutter thus leads to widening the upper surface of the wall, and the load of the balustrade requires a strong support by the lower cavetto. The walk is then set back from the outer edge of t the upper part of the cornice, and this upper margin receives the form of a wash.

Instead of foliage, these cavettos are also sometimes filled by figures cut from the mass of the ashlar (Fig. 1002(., cornice beneath a gallery on the south bower of Strasburg minster.

Belt courses, parapets and hoods.

Besides the architectural problem to separate two parts of t the wall lying over each other, to crown the lower or serve as a support for the upper, there comes in question here mouldings, for which the problem is almost entirely to cause water to drip off. Either they have to allow a great amount of collected water to run off (like cornices beneath window parapets),or they have portions of the wall beneath them, or also to protect dangrerous joints from falling water (for example hoods).

Formation of the edge drip.

Therefore these mouldings as a rule require anstrongly shaped wash or a drip, since they may be lacking on main cornices with projecting margin of the roof; but to change such a roof cornice as shown by Figs. 992 to 999 into one of the preceding kind, is conversely from the profiles given under Figs. 1003 to 1007.Figs. 1003 to 1008 contain some transformations of the proportion of projection by the form of the upper edge. The most of these profiles show projections equal or approximately equal to the height, only those are exceptions to this proportion in which by the omission of the lowest member occurs a reduction of the height. This most easily results by extending the overhanging part a in Fig. 1000 downward, so that by the addition of a cove tangent to the face of this member results the form in Fig. 1003 and that of Fig. 1004 by retaining the compound member given in Fig. 1000. Both forms are taken from the west front of the church at Haina. This extension of the margin may further occur by addition of a round or of an entire or half ogee hollow to the chamfer a b in Fig. 1005. If then in this case the centre of this

moulding be moved out above a b, it is next to form the upper wash in a flat curve tangent to the curve of the round, as also given in Fig. 1005.

The same result of an enlarged undercutting can be obtained by making the cavette a pointed arch, which usually occurs on churches in Mühlhausen; it is shown in Fig. 1006. But most decisively is this result attained, when the moulding is exclusively cut in the horizontal under surface of the arhlar, and only the front edge of the stone has a chamfer as other moulding.

Thus the proportion of the projection may also become predominant by a lesser inclination of the wash, as from a to c in Fig. 1005 or from b to c in Fig. 990. It then depends on the nature of the stone whether the upper edge b remains acute angled or is to be made a right angle by the changed direction of the wash. The best assistance in this case is afforded by the form of the upper moulding as a round or ogee moulding.

The preceding Figs. mostly show a wash inclined at 45°, so t that they may be regarded as shaped from the ground form of the square set diagonally, and thus the latter may also be replaced by the equilateral as shown in Fig. 1008, whose construction is explained by the aiding lines given.

Inclination of the wash.

In the church style these flatter inclinations of the wash f form an exception particularly belonging to the last period of Gothic. On the contrary in secular works in many cases, for an unusual depth of the window jamb, it may be preferable to reduce the height of the wash of the sill by a flatter inclination, and to continue this over the edge of the projection of the edge of the sill forming a drip. But since the woodwork of the window frame rests on the upper edge of the sill, and thereby is desirable a rapid removal of the water nearest this, either the line of the wash can make an abrupt bend there or be raised by a curve (b in Fig. 1009). Then the wash of the edge of the member may also retain the original steeper inclination and form a bend next the sill.

In the better periods of Gothic art occurs the converse case, that the inclination of the wash is steeper than the angle of 45°. These steeper inclinations were then either carried over the projection of the member, or form at the face of the wall an angle with the wash of the latter inclined at 45°. Particul-

Particularly commonly are found such forms on the offsets of t the buttresses, where sometimes the wash inclined at 45° may seem too weak to transfer the load from above to the under and larger surface, but on the other hand made necessary the formation of this wash in two blocks, and hence the arrangement of a bed dividing them became necessary (a b in Fig. 1010). But with a less steep form the latter would have had too acute angles at a. On English works is sometimes found the joint made easier by fillets, chamfers or undercuttings, that break the surface of the wash and afford a right angle for the blocks. (Fig. 1(10 a). The same steep wash is sometimes found on the sills of church windows and finished at the inside edge with a shallow channel (c in Fig. 1010), which prevents the water from dropping that runs down the inside surface of the window. On many smaller parts like crossflowers, the function of the wash is neglected, where the little moulding (a in Fig. 1011) with the horizontal surface is attached to the stem. But here the joint lies not above but below the moulding, and therefore the horizontal surface cannot be injurious. Since also as a rule even a complete wash would not be provided below, thus the wash found at a is rather to be regarded as a chamfer of the front edge.

Hoods.

As at first were mentioned the caps of parapets, then everything said applies likewise to the proper hood mouldings, that occur above reliefs, inscribed tablets, or even richer jamb mouldings. For such purposes are suited the profiles given in Figs. 1003 to 1008, as well as part of those given earlier.

Belt courses.

The same forms are also assumed by belt courses, which indicate the floors of buildings in several stories, but at the same time serve to keep dry the wall surfaces below them, as Figs. 1012, 1012 a show. For while in the rain driven under b strikes the entire height of the wall, in the latter are formed dry places under the belts c, d and e with the same inclination of the rain, which then facilitate the drying of the remainder of the wall. Particularly the water running down the wall from above will be thrown off by each belt. The driving of the dropping water back against the wall does not occur in a moderate wind on account of the larger drip.

By a steeper inclination of the wash these belts may become also caps of balustrades. On the belts which neither at the joint adjoin woodwork or another inferior material subject to easy injury, like the caps of balustrades of galleries, the wash ceases to be imperatively necessary, and in some cases may be replaced by a horizontal surface as in Fig. 1013. Also the undercut may be omitted (Fig. 1013 a).

Junction of a roof.

Frequently the problem of the bect is to protect the joint between two different materials, and it especially occurs where a roof joins the face of a wall, no matter in what direction. The usual practice of the mason has neglected in modern architecture this protection, and aside frim lead flashings has sought to replace it by a slight projection of the part of the wall above the junction of the roof. In a far more perfect manner is this attained by a belt with drip inserted directly over the l line of joining, which thus in the simplest case has the same relation to the face of the wall as the moulding b in Fig. 1010 a to the wash beneath it. A very clearly treated example of this kind is found on the sacristy of the church of S. Martin in Cassel, where over the junction of the roof and a window with the face of the wall, the moulding rises in a gable line and ends in a crossflower at top.

Corbelled members, Handrails.

Corbels are already in part contained in the given profiles. Thus these are to be counted with all those parts of cornices, that support channels or balustrades, thus the lower cavettos in Figs. 997, 998, 1000 to 1002. A corbelling in the proper sense is further formed by the parapet cornices on the north side aisle of the Strasburg minster (Fig. 1014), in so far as the upper face of the wall against which stand the jamb columns a , project beyond the lower and place the bases of these little columns even out over the extreme edge of the member.

For this last projection accordingly is not arranged a proper corbelling, but it supports alone by the combination of the stone of this base with one of the bonded cornice stones. Here is a corbelled profile of the projecting base of the columnis omitted, which was perhaps originally intended. The entire design has a great effect by its bold projection, but is still not exactly beautiful and indeed is only based on this, that since

every parapet wall without load needs no great thickness, the upper width of masonry necessary was to be obtained for a passage extending around before the windows in the interior, by this corbelling is to be placed in connection with one lying somewhat lower inside , and the blind arcade extending beneath the windows, whose columns stand before the internal corbelling.

On a larger scale are found such corbellings beneath bay windows, turrets or balconies, or even entire stories. They may then either start from the capital of a column or pier as on p pulpits, or from a point in the face of the wall. The most common of these arrangements expresses the corbelling out of the roof gutter, according as the floor of the bay window is coposssed of one or more stone slabs, which then projects from the face of the window in the form of a moulded drip moulding (a in Fig. 1015), and lies on the mass of the projection. The latter is shaped in the simplest case as an inverted frustum of a pyramid (Fig. 1015). But its angle of inclination must be tolerably steep, so that the angles of the blocks may not become more acute than permitted by the resistance of the stone. More freqently the corbelling shows members placed on each other.

On the cathedral of Chartres little basins like pulpits project from the roof balustrade above the flying buttresses, whose corbelling starts from a pier capital indeed by the repetition of that given in Fig. 1000, consisting below of a cavetto decorated by leaves. By this results the form of Fig. 1016.

In the later Gothic has striven much to make the very frequently occurring corbellings with the greatest simplicity by a mere repetition of cavettos undercut or sometimes as on the bay window of a private house in Erfurt (Figs. 1017, 1018), sometimes with the richest combinations of mouldings, of which an example is shown in Fig. 1019. The separate members must always follow a simple or compound principal line, and the latter results most naturally by starting from the originally rectangular form of the separate ashlars.

As a member required by a special purpose the handrail of stairs is included here. The principal member must be a round filling the hand in a convenient way. For detached stone railings this purpose is attained as in Fig. 1020. Handrails in the face of the wall are cut in the bonded ashlars, and in certain cases do not project at all beyond the face of the wall, but are prod-

produced by coves sunk above and below (Fig. 1021). The end joints of the ashlars intersect the member at a right angle.

Members of the plinth.

Romanesque plinth.

In the Romanesque period, besides the wash always occurring at 45° or the flat cavetto replacing it (Figs. 1022, 1023 from the church at Moringen), there appear arrangements of hollows and rounds, that often correspond to the Attic base, but sometimes even exhibit a richer series of mouldings. A Romanesque profile occurring particularly often is the cavetto with a round beneath as in Fig. 1024 from the church at Weiprechtshausen and Fig. 1024 a from the monastery church at Loccum, and it is again found almost unchanged in many Early Gothic buildings, and elsewhere it also reappears in many simpler Gothic profiles (as in Figs. 1025, 1025 a) in earlier and later profiles from the church of S. Alexander at Einbeck.

Inclined planes or hollows.

In these members is clearly expressed the function of the plinth, it does not crown like the cornice or protect lower parts, but it has to carry the pressure of the upper mass of the wall to a broader base and to show the projection thus arising. Both functions are entirely fulfilled by the simple slope or wash, which therefore is almost always employed on simple buildings, and sometimes even on quite rich works on account of this special fitness, and thus the base on the Strasburg minster is a simple wash beneath a richly moulded cap represented in Fig. 1024. The spreading of the upper pressure is yet clearer by the wash in form of a flat arc, Fig. 1023 and a in Fig. 1026, that receives the next addition of a wash or other member of its lower edge b or c (Fig. 1026).

Compound members.

To express the ashlars of which is formed the profile of the plinth, this hollow is commonly separated by a remainder of the wash e in Fig. 1026 from the face of the wall, into which the hollow d directly passes. The low position of this member however causes it to be chiefly visible in direct view, but on the other hand its nearness to the eye makes a more complex form desirable, that was sometimes found in a profile hindering the floww of water (Fig. 1027), where the arc a in a sense forms the channel surrounding the base of the building, in which rain-

rainwater stood until dried out. But since this lower part of the wall otherwise is in constant contact with the damp earth, and since further other channels and even water basins made of stone, then this standing of water just in this place can do no injury, except that the joints are washed out and the projecting front margin is removed in the course of time, a removal occurs of itself, and the profile in Fig. 1027 is changed into the indicated form. But how slowly this alteration proceed is partly shown by the profiles of plinths of this kind dating from the 14 th century, as in Nuremburg, Mühlhausen, etc., that have retained this raised margin. Yet this form appears in a sense to be a transfer of forms from the interior to the exterior, a and therefore must be avoided, since it serves no real purpose, and hence is better formed at first according to the changed shape of the edge indicated in Fig. 1027.

On more important works the profiles of plinths are formed of two courses, and then also consist of two profiles separated by a vertical band. The height of this band is then decisive for the character of the whole. Examples of this kind are shown in Figs. 1028, 1029, the first from the church of S. Blasien in Mühlhausen with an indication of the rectangular form of the ashlars, the latter from the choir of the cathedral in Erfurth formed of the wash. Of such a kind are the massive profiles of the plinths of the church of S. Maria at Mühlhausen.

It is self-evident, that for the members of the plinth should always be selected, as generally for the entire base of the building, stones particularly permanent in the weather, and the same applies to all strongly projecting parts. On plinths and bases of columns and piers further see p. 212.

3. Architectural Treatment of the Buttress.

General form of the buttress.

Required dimensions.

The general form and dimensions of the buttress were specially treated in the earlier Sections, to which we therefore briefly refer here. First was demonstrated on p 125 to 127 what form of elevation would be most favorable for the effect alone of the wind (Fig. 343), and what types of elevations are chiefly followed in executed buttresses (Figs. 344, 345, 346). On pp 163 and 335 are then considered other side forces and especially wind thrusts, it was shown there (p. 335) how under their influence

might be required not only increased strength, but also a changed form of the elevation, while side forces applied very high made too great diminution of the buttress unsuitable, and it m must rather be carried up in approximately uniform dimensions. The calculation of stability against wind thrust was explained on p. 163 to 170, and further the calculations for different examples of buttresses were made on p. 336 and 402.

Taking a buttress like that of Fig. 1030, the following course of investigation must be recommended. First is obtained with only the effect of the vault thrust the location of the pressure in the base I and the top of the plinth II or II a (p. 140), and there is determined in the given case the stress occurring in the material (p. 143 to 145). Then is added the effect of the wind, first from the left and then from the right, and the resulting displacement of the pressure is found.

With the wind from the right in some circumstances occurs a greater side force S, which then makes indispensable also an investigation of the stability for the section III. If this force S be nearly horizontal, then must one consider also whether a sliding of the upper masonry can occur at the bed IV, or V, or one lying still higher (p. 340). In case this is to be feared (i.e., if the resultant of S and the loads varies less than the angle of repose from a perpendicular), the upper loads are to be increased correspondingly by masonry on the buttress or the side walls. On an investigation including the side arches or t the upper part of the wall with this, see p. 338 to 342.

Offsets.

If the dimensions and general form of the buttress are determined, whether indicated by accurate or approximate calculation, by empirical rules (p. 273), or by direct estimates based on p personal experience, then it is next to treat it architecturally. For practical and artistic reasons one seldom reduces the buttress with a single slope or batter from bottom to top, but in both thickness and depth reduces the mass, and whose copings as well as the upper termination of the buttress can afford opportunity for the most varied forms. The mass taken away by offsets at one place must me more or less added again, and the offsets must not be cut too deeply into the body of the buttress, and in any case must not be exceeded limits, as indicated by oblique lines in Figs. 1032 to 1034. The offsets must generally

not be too great and not effect changes in intermediate cross sections.

At an abrupt offset as shown by Fig. 1031, the force D in the upper part would exert a strong pressure near the edge A, that must be transferred to the point C of the lower part. On the contrary the directly adjacent point E that has no load and has a pressure = 0, so that the danger of shearing increases between the points C and E, in fact here with the small resistance of the stone masonry to thrust or shear may result very easily a separation of the parts, which continues far below in the form of a crack, as can be frequently observed on old and new works. (Moreover it not rarely occurs besides on secular buildings on the parapet wall beside strongly loaded window piers). The old masters did not overlook this point, they used here particularly strong ashlars, or they also used cramps, and in brick buildings there was sometimes alternated here the positions of the courses.

But it is more effective to make gradually the change in cross section corresponding to the spreading of the pressure, which is to be effected by steep slopes, inserted gables or other partly transmitting and partly loading pinnacles or the like.

If the buttress has only one offset, it naturally finds itself placed at the height of the internal capital or springing of the vault, for at this place occurs the thrust of the vault, which requires an enlarging of the abutment downward; by the projection would also be indicated on the exterior the point of application of the internal thrust (Fig. 1032). Instead of one may exist two offsets, one above and the other below the capital (Fig. 1033); the latter can be placed so far downward that it combines with the sill course (Fig. 1034). If the number of offsets be further increased, they may be of uniform size or be alternately larger and smaller. The division in height can either make one part predominant, an equality, or exhibit a pleasing reduction or a rhythmic change in heights, but the relation of the different parts to each other must be clearly expressed and easily perceived.

With the projection in front may be combined a more or less great projection at both sides of the buttress.

In the instructions of Lacher (Note) the height of the capital in the interior determines the height of the lower end of the

offset of the so-called drip moulding. Thereby the before mentioned importance of the offset is indicated in the clearest way. For the dimension of this offset is found there the rule, that its area above this remains square, if a pinnacle stands thereon. This determination must at the same time also indicate a limit of diminution for the simpler form. Where as on the church of S. Elisabeth in Marburg and the church in Wetter, the part of the buttress above the drip moulding finds itself smalles, there is to be sought its ostensible purpose in the support of the gargoyle, while the proper buttress ends with the supporting mouldigg.

Height of the buttress.

Note. Reichensperger. Vermischte Schriften. Leipzig.

As for the height at which lies the termination of the entire pier, for this is set a maximum for ordinary cases, that the cap stops beneath the bottom of the roof cornice or of the gutter. It extends exceptionally to the upper edge of the cornice, so that the roof of the bulilding projects over the buttress as on the church at Haina (Figs. 1035, 1035 a), or the roof cornice extends around the buttress and its cap, adjoining the balustrade of the roof cornice in which the buttress here appears favors the united effect of the whole, and therefore is effected in another way. Thus are found on many early French works on t the low cap of the buttress is set a part reduced on all sidss, whose projection equals the projection of the moulding. This portion of the buttress then stops under each projection. Such an example from the choir chapel of the collegiate church of S. Quentin is shown in Fig. 1054 at a. Sometimes that part of the buttress is replaced by a column, whose capital grows out of the cavetto beneath the gutter (Fig. 1055).

Other combinations result from the arrangement of the gargoyles, as well as from the pinnacles placed on the buttresses, t that can be developed with particular freedom, if the buttress rises to receive a great load above the height of the cap.

Caps of the buttress and of their offsets.

Cap in the form of a shed roof.

Figs. 1032 and 1033 contain the simplest form of cap, namely that of a shed roof leaning against the wall. The rate of inclination is arrarged according to the construction, as a horizontal position of the joint requires a steeper direction (Fig.

10 7), and a joint perpendicular to the inclination allows a flatter one (Fig. 1038). With the last construction, that results from the use of mixed materials , the beginning aud also the close of the coping at a and b must be bonded at right angles to the buttress and the wall. If according to this construction the ashlar lies at top with a bed resisting the weather, for it is still the disadvantage, that the joints are more exposed to the penetration of water than in a horizontal position.

The sides of the buttresses that remain without protection in the form assumed in Fig. 1032 may receive such by the breaking and coping around (Fig. 1033). The wash of the latter may either have the direction of the cap of the pier or be flatter, hence with a bend formed against it (Fig. 1033 a).

The next addition consists in a moulding accompanying the angle of the coping of the buttress, that stops on the horizontal wash (Fig. 1037), and either is different or the same profile as the latter. Thereby results further a stopping of the horizontal moulding at the side surface, so that only a short piece extends around the corner (Fig. 1039). Most simply the horizontal profile directly forms the horizontal (Fig. 1040), but not well possible without a distortion of the profile.

A bending of the gable moulding horizontally (a b in Fig. 1041) forms the simplest means of breaking it around the corner and so connecting it with the horizontal continuation, so that the profile remains unchanged, and it also finds its application to actual gables of greater dimensions.

The length of this piece can be reduced so that the inclination of the roof starts according to Fig. 1041 a near the extreme projection of the horizontal moulding.

In the later periods the bends on buttress caps are found replaced by a concave line of inclination of the coping as shown in Fig. 1042. Indeed the purpose of an unbroken course of the profile is thereby obtained in but an imperfect way, and there always occurs a distortion of the latter increasing with the radius of the curve, and hence is most striking when the line of inclination is again straight.

This combination of the gable and horizontal mouldings can further be attained by omitting the return, with an intersection (Figs. 1043, 1044), an arrangement that allows entire freedom

to the profiles of both mouldings. In certain works of the later periods the mouldings are prolonged beyond the point of intersection and then cut off at right angles. But further the intersection may also be avoided by placing a neutral body between them on which both die (Figs. 1044 to 1045 a). On earlier forms of this kind is expressed in a certain manner also the function of support in the form assumed for this intermediate and free volutes extending from the angle of the buttress, as likewise made the ground motive of the form of a capital (Figs. 1044, 1044 a). Instead of these was also an animal form, a head or finally a freer form of leaf could appear, which usually scrolls from the lower member of the gable moulding (Figs. 1044, 1045 a), then merely forming an intermediate. Since now in the Early Gothic period those volutes also serve the most varied purposes and a purely intermediate character, this in later times is true is true of the pinnacles, which therefore also appear here in a position corbelled from the angle of the buttress, and both alike or different mouldings can stop dead. Thus generally all general conditions are reflected in this apparently trivial detail.

Combination of shed and gable caps.

By the arrangement of the simple shed cap the water drops from the drip moulding of this on the lower offsets. But over the angles the water can be led by the combination of the shed roof with a gable above the front side of the buttress. (Fig. 1046). The gable may be formed with or without a projecting moulding resting on a horizontal moulding, or it may be in connection with bordering the shed roof in any manner. Further the horizontal moulding can also be omitted and the gable moulding be cut off abruptly in the side surface, the gable may extend over the entire width of the buttress or may have a smaller breadth, the gable roof may extend horizontally along the shed roof, or the ridge of the same can be parallel to the inclination of the latter.

As for what concerns the profiling of all such inclined mouldings, an intersection is not absolutely necessary, since the w water running over the front edge down over the hollow or chamfer will flow away at the angles; therefore it contributes a c characteristic form differing from the ordinary profile of the drip moulding. Of ugly effect is especially a too great height thereof. Hence an exact proportion of the height of the gable is not to be fixed, since in smaller dimensions this must be

greater than for small dimensions; generally suitable proportions can be found by dividing the base of the gable into 6 or 9 parts.

Above the angles of the buttress the gable moulding meets one accompaning the slope or lying on the longigudinal surface of the buttress, and thereby may result long hanging points according to the nature of the stone (a in Fig. 1047). Hence they are generally cut off at the line b c. But further is arranged a corbel beneath the surface so resulting, or finally is employed such a one with a horizontal form (Figs. 1044, 1045). The arrangement of a pinnacle at the point in question leads to the fully developed system of the intersecting gables on the pinnacle.

For a complete regulation of the course of the water above the angles is further very necessary an elevation of the gable moulding above the roof surface, as shown by the Greek cyma, and t that here as a rule is formed by a returned gutter;. Thereby a are formed water basins above the angles, and hence the need of spouts or gargoyles. Fig. 1046 shows such an arrangement.

Covering like a gable or hip roof.

Instead of the compound roof design is usually found a simple gable or hip roof extending along the depth of the buttress in a horizontal direction to the face of the wall (Fig. 1034), which again may receive a richer form, so that it is penetrated sidewise by one or more.

On German works the roof surfaces are generally left smooth. On English works are usually found the rectangular or undercut form of the edges of the separate ashlars, and on the French is the scalelike theatment of the surfaces with rectangular edges. (Fig. 1046). This essentially contributes to the animation of the whole and shows how skilfully the ancients understood how to give to a part a decoration corresponding to its function, and at the same time to facilitate the removal of the water. (Viollet-le-Duc, V, p. 101). On the form of the gable this work on the surface has an influence, since its profile can form the limitation of the line of the gable (Fig. 1046 a). For a raised gable moulding it runs on the contrary (Fig. 1046).

The gables either remain plain or can be filled by a circle, trefoil, tracery or foliage ornament. If the horizontal moulding is wanting at the base of the gable, as a rule there a blind a arch is in the gable.

The ridge of the roof of the gable would only be sufficiently obtuse that its slight inclination to be executed, and it therefore could be strengthened by an accompanying round or pointed moulding (a in Fig. 1046). The profile of this member forms in front view the simplest form of crowning of the gable (Fig. 1048). A more perfect form of it would be obtained by placing on it a stem with knob. The motive of this arrangement results from the construction of the pyramidal stone roof, as shown later, but likewise from that of the wooden gable roof, and it forms a detail much exposed to overloading in form and size. Therefore we shall attempt in the following to give some developments of such forms certainly based only on views od mediaeval works.

Let the triangular gables in Figs.1049 d, b, c, whose heights equal the base with a cornice an eighth the height of the latter, the side Fig. 1049 a shows a section through the ridge. If we now assume that the lower joint of the stem set thereon passes through the point a, then will e f be the rise of the required ashlar, thereby determining the projection of the crocket. But in any case even with a varying location of the joint there results by the verticals erected at a and f a relation of the size of the crowning to that of the crowning of the gable cornice. The lower size of the stem is then found by an extension of the line a l to the side of the triangular gable and thus to m, the upper by the triple division of i k. According to the assumption of the intended form, further considered below, of half the side of the square on i k remains to e g and f h in the section in Fig. 1049 a behind the projection of the gable, so that the stem is set back from the front face. Different determinations of the dimensions are contained in Figs. 1049 b, c, where the width e f is always taken as a masis.

A development of the height of the crowning from that of the gable is unsuitable, there occurs almost a converse relation between both. Evidence of this would be given by trial, that for the low gable in Fig. 1049 d the assumed proportion would exceed that represented on the steeper one in Fig. 1049 d.

In general a polygonal section of stem and knob is preferred to a square one, by which an excessive size would be produced diagonally. The polygonal stem can then intersect the roof of the buttress or return to the square above the junction, and in any case occurs an intersection with the moulding crowning

the gable (Fig. 1049 c). If the gable cornice ends with a drip above, the polygonal stem usually has the position given in Fig. 1050 in plan on the upper edge of the drip, and there is found either as in Fig. 1050 a, b, a transition by a bending of the angles of the stem, or a simple intersection occurs of stem and gable cornice. The form of the gable becomes richer if it is adorned by leaf buds or edge blossoms, which are then best placed at the middle of the stem (Fig. 1050 e.

Covering the offsets.

Everything said here concerning the caps of the buttresses a applies in like manner to the covering of the offsets. But it is in the nature of the matter, that all combined forms require a certain size of the setting, while every small offset of only a few inches is satisfied by arranging a simple shed roof with drip moulding.

Side offsets in the dimensions of the buttress can be connected with those in front and thus with the front shed roof, and then either as in Figs. 1051, 1051 a, the drip moulding may extend along the sides of the buttress or be omitted as in Fig. 1051 b. In Fig. 1051 a the inclination of the roofs on the different sides need not be the same, so that thus a different size is obtained.

Further each of the forms shown above for the caps of the buttresses may also form a composition placed on the buttress diminished on the sides. A compound arrangement of this kind is shown by Fig. 1054. This form may be changed in a particularly effective way, so that the piece on the buttress reduced in thickness may be combined with that set on the buttress reduced only in depth (Fig. 1052). Such forms are found on the towers of the south transept of the cathedral at Laon as well as on the central tower there (Fig. 1055), and produces a good effect especially by the multiplication of the angles. On the contrary on English works is sometimes found a simple chamfer of the angle, which then in a richer way is obtained by rectangular recesses in them with inserted little columns, so that cap and base form the transition to the right angle.

In the later periods of Gothic art the cap is usually formed by one or more of the ground form to the diagonal, and thus likewise is made a multiplication of the angles, that is then led on certain works to a semicircular ground form of buttress.(Fig.1053

Enrichment by blind arches and shrines.

Blind arches.

The richest ornamentation of the buttress results from the use of blind arches, capable of the most diversified forms. The adoption of these makes necessary an enlargement for the material cut away by the blind arches, and the members of the blind arches best project entirely. Lacher says of them:- "It is then best that thou wilt break it up with tracery, so leave only its length and thickness." The buttress of the church of S. Quentin r represented in Fig. 1056 forms in a way an Early Gothic illustration of this text, so far as shown in Fig. 1056 a, the blind arches are formed by little columns projecting from the front surface, which stand on the lower projection and support the arches inclosing the blind recesses joined to the mass of the buttress

If the blind arches e?tend around the buttress, then would be necessary an increase of its thickness by that of the columns. Richer arrangements result from upper and lower divisions as in Fig. 1056 a, whereby only the former and larger columns of an entire piece project, and the smaller ones are wrought on the ashlars of the nucleus. Thereby either the former can be accompanied by the latter as by wall pilasters (right half of Fig. 1057), or only receive the arch on its capital, as shown by the left half of the same Fig.

On the buttresses of the clearstory of the church of Mantes are lacking the arches set on the columns, and their capitals directly bear the roof of the buttress. In the converse sense are found to predominate in the late time the arched members in vertical spandrels extending down to the base, so that the columns consisting of pieces are omitted, and at most recur still in the capitals and bases by which the rounds of the members extend downward are ornamented.

To the arched work and tracery is applicable what is later s said of window tracery,. But a peculiar condition concerning the height of the arches results if the blind arches enclose a part of the buttress terminating in a simple gable roof. For here the height of the capital is determined by the need for t the crown of the arch to remain below the horizontal cornice of the gable roof. Therefore the arch on the gabled side must either recede to a greater depth below the line of the gable as at a in Fig. 1056, so that in a richer form above there can be

found a place for themselves, as it were by accident.

The proportions of the little cottages and villas may be
enlarged in different ways. In the case of [illegible] is evi-
[illegible]
[illegible]
[illegible]

found a place for tracery, or it must be stilted.

The proportions of the little columns and mullions may be developed in different ways. In the plan of Fig. 1057 we employ the proportion of 1 : 4 as mentioned elsewhere in regard to the window mullions, so that the entire width is divided in 54 parts, of which each division receives the inscribed number of parts. This proportion is also one suiting open shrines, where the interior is vaulted, since it about agrees with the thickness of the abutment for the stress in the arch. Meanwhile in the case mentioned yet a little increase occurs with regard to the square form. To entirely similar results leads the geometrical construction represented in Fig. 1057 b. In this a b is the entire width of the surface concerned, a c and b c are the diagonals of the square formed thereby, so that half the difference of b both lengths determine the diagonals of the angle square adef, and the intersection of these with the diagonally placed equal area g h i k gives further starting points for the form of plan of the arch members and of the little columns placed beneath them. Thus on the assumption of a combined arch system with large and small mullions, the plan of the latter being imitated for the corresponding part of the larger in both halves of the Fig. in different ways. Meanwhile also in regard to a single blind arch the small mullions vanish and generally the form of plan becomes simplified, about as shown by the finial represented in Fig.1057.

As generally in smaller proportions an enlargement of the projectingsparts , an addition of certain dimensions connected with the natural conditions occurs, so that such a one is first given for the analogous blind arches of the body of pinnacles as given by Roriczer in the "Little book of correct finials(Figs. 1067 to 1067 e)aand p. 458.

By removal of the masonry nucleus and covering the resulting open space became the parts of the buttresses furnished with blind arches at Gelnhausen, that first serve to receive figures.

Shrine with horizontal covering.

The simplest form of this is that mentioned above and allied to the buttresses of Mantes, entirely separated from the vaulted construction, while from the free columns to the back wall, thus a slab is laid over the buttress and on the latter is placed a gable roof. Fig. 1058 shows such a form from the south transept of Strasburg minster, which occurs still later on the south tr-

transept of the church at Colmar, as well as also on the cathedral of Chartres and other French works. In a richer form this arrangement is found on those two intersecting gable roofs and the placing of a crowning over the crossing, this almost leading to a colossal pinnacle, like this development in Colmar, there indeed in very low proportions. On account of conditions and generally from the severe character of the detali forms peculiar to that early time, still the horizontal covering becomes nowise peculiar to the transition style and is to be regarded as contrary to the Gothic principle of construction. It is evidently not the latter, for so may be developed tha vaulting system always, and thus in no period is excluded the horizontal covering. Everywhere appears the latter as an extension of the former, indeed as an independent form of covering, where permitted by the span to be covered. Accordingly it is decidedly in the nature of Gothic art to develop the entire structural form into an art form, i.e., to employ all those details, in which the decorative character appears in the foreground. When further Gothic art in this very rapid development soon passed from these forms of the early period to those more graceful produced by the development of vaulted construction rests more on the choice of these ornamental forms of details, than on the recognition of the incompatà bility of the earlier basal motives with the fully developed form of construction.

Shrine with tunnel vault.

A symmetrical support of the slab results when the columns are connected with a back wall by stone beams laid across and project inside, which either form the entire mass or bear a gable roof constructed of inclined slabs. Fig. 1059 exhibits such an arrangement, that in its further development leads to a tunnel vault, indeed first to one formed like the trefoil arch, by a repetition of the corbel form at top; Fig. 1060 then shows a tunnel vault, whose pointed arch is then included within the triangular gable, while those stone beams form its abutments; Fig. 1060 a shows the plan of the little columns at a greater scale with the moulding at the front of the vault and the stone beams, and Fig. 1060 b is the section. The jointing is arranged according to the magnitude of the whole and in smaller dimensions wouldlead to the combination of the vault with the roof in two pieces with a joint at the crown of a member covering it and

forming the ridge.

Shrine with cross vault.

Meantime the tunnel vault is also soon found to be supplanted by the cross vault (Fig. 1061), and there is indeed expressed a least apparent result of this course. For the principle may well be established, that since onle the system of chross-vault determines the entire body of the structure and in general the development of all its members, the exposition of this condition in all dimensions is required, as soon as it concerns covering a space, and this explanation may appear grounded, when the circumstances allow it to form the entire covering of a single block, since it concerns only the imitation of a structural motive for a decorative purpose. But when the proportions of the space to be covered lead to vaulting with actual joints, it will be required to appear by a higher result, just to adopt the form of vault best suited to the conditions and dimensions. Thus we find the tunnel vault in the best period of Gothic frequently maintains its place beside the cross vault, as above the passages extending before the windows (p. 855), as well as over the projecting porches of the cathedral of Amiens and that of Chalons built between the buttresses. Indeed we even see it developed particularly to a richness, that excels all later applications of it, such as brought by the Renaissance and Rococo styles, and even affords a rich substitute for the more varied lines of the ribbed vault. If then and particularly in the later time the cross vault also in cases where the proportions of the ground form and the considerabel difference of its sides first requires the tunnel vault, as in the example last mentioned, and even appears with a certain affectation, no blame will be expressed here, but only will be asserted the freedom of the use of the simple form of vault and first in regard to the shrine. Certainly diversity will be obtained thereby without damage to unity.

To buttresses, little columns and capitals on shrines covered by cross vaults apply what has been said concerning piers and vaults.

Supports of the shrine.

In Fig. 1057 a we take the square a b c d found in 1057 as a basis, from which result the dimensions of the separate parts of the arch as of the little columns forming the buttress. Instead of the buttress there could be a single column according

to the earlier mode be arranged, or according to the later buttress with attached little columns. The ribs require by their small dimensions a simple moulding, a round or pointed bowtell, or this can be replaced by the compartments in which the ribs meet.

Proportion of the height of the shrine.

The proportion of height of the shrine are made moderate on the older works, about 3 : 1 to 4 : 1, and so far dependdon the figure to be established therein, so that the head of the latter may not rise above the top of the capital as a rule, but more commonly remains below it. More slender proportions are obtained by the arrangement of blocks or pedestals on which the figure stands, and further by placing it in a free column. Smaller columns are usually employed by arranging iron anchors at the height of the base of the vault.

Form of plan of the shrine.

The ground plan of the shrine is square or rectangular. The latter form in the proportion of 1 : 2 in the interior can be combined with the square form of the exterior in the manner shown in Fig. 1061. Yet the rectangular form is also fully exposed, and is even connected with a concentric form of pointed roof, so that the excess of the side of the latter beyond that of the shrine either intersects the face of the buttress or rests on a projection from it, and hence the middle line of the roof of the smaller side is entirely separated as at Rheims. M Moreover such irregularities were never feared, since then merely heightened the picturesque effect.

Likewise the polygonal plan is sometimes found, first that of the hexagon so that the shrine proper projects from three sides of the hexagon, and a niche made in the rear wall completes the entire polygon. A polygon with more sides would cause the disadvantage, that the columns would conceal the figure. Yet such a defect is sometimes avoided by replacing the two front columns by suspended springings of arches.

Crowning the shrine.

The idea lying at the base of the use of the cross vault on these details is that the decoration of the principal form of the whole becomes the most definite expression, if there is assumed over the vault a horizontal cornice and above theis a gable roof with gables over the front, just as over church vaults are found ceiling beams with a roof above them. With a square

ground plan the same treatment of the different sides leads to a repetition of the gables above the sides, and thereby to the arrangement of two intersecting gable roofs. Further the endeavor for greater lightness leads to the omission of the horizontal cornice and to raising the vault into the interior of the intersecting roofs, whose surfaces then form only the external surfaces of the vaults. But the intersection of the roofs makes a s special accenting of the point of intersection by an ornament an esthetic necessity, just like the intersection of nave and transverse aisle demands the arrangement of the central tower. The nearest form of this addition is the pyramid, i.e., the great pinnacle by which the charcater of the shrine passes into that of a hollow finial. Thereby the weight of the mass of the omitted nucleus is replaced by that of the figure of a saint placed in the shrine, and certainly a happy thought lies in this, that of expressing in the stone construction the strength imparted to the church by the importance of the saint.

With the buttress may be combined the shrine in different ways, either forming a termination of it or an offset. In the first case it lies in the wall surface or rises above its top, in the latter it either lies before the top of the buttress in a smaller width or has the same breadth, so that the architecture of the shrine continues as blind before the solid mass of the buttress.

Buttresses exterding to the roof gutter and carried above it.

Also the relations are of the greatest importance, that the buttress has to the gutters and spouts.

Supporting the spout for water.

The simplest arrangement consists in this, that a part of the buttress in its thickness bears the spout, as on the choir of the church in Wetter (Fig. 1062). In the simplest case it has the same width as the spout, but may exceed it, so that it may project beyond that and the excess receive a cap under the spout, and for more ornate designs a little column would project from the buttress, on whose capital the spout receives another bearing. Such an arrangement appears to be intended on the buttresses of the eastern bay of the south side aisle of the church at Haina.

On the cchurch of S. Stephen in Mayence is then found the ar-

arrangement represented in Fig. 1063, where on the gable roof of the buttress is set a detached column, which supports the spout, where a strongly diminished part of the buttress formed as a square set half diagonally forms the first support of it, so that the adoption of this ground form beneath it occurs in connection with the chamfer bordering the lower edges. On the same construction is further based the frequently occurring design, according to which the column is replaced by a detached pinnacle (Fig. 1064), in the body of which the penetrating spout forms a course, so that the upper part or the body of the finial is ensured by loading the entire construction.

On S. Benigne in Dijon is found the form shown in Fig. 1064, which offers a suitable motive for the arrangement in question. Indeed the same appears to be substantially modified in reality and we have not been able to obtain the existing direction of the water therein. Therefore we give Fig. 1064 from a sketch w with the spout placed at its foot with only the addition of the front mouth of the spout projecting over the pinnacle. The absence of the spout indeed permits the possibility of a later change, so that the pinnacle forms or contains a vertical tube, through which the water is conducted to the gargoyle. The arrangement in question is further found in full activity, though in simpler form on the towers of the church at Volksmarsen.and on that in Wildungen.

A design belonging to the early time of Gothic art is further shown by Fig. 1065, where the buttress is enclosed by the roof cornice, so that on its upper surfaces is formed a water basin, from which the water runs into the spout placed beneath. Next this would be the last arrangement, whereby the width of the basin is divided by a gable roof so as to leave at each side a gutter extending to a spout. There the gutters like the gable roof may be inclined, and the spout be replaced by two spouts set diagonally.

Extending the gutter around it.

The division of the upper surface into two gutters then chiefly occurs with entire necessity, if the buttress has a projecting part or a pinnacel rising above the gutter, the water being carried around that higher part instead of through it. We find these particularly on the buttresses of towers and on the arrangements in other places in connection with the buttress system,

and mention here only those of the S. Chapelle in Paris, where the buttress is enclosed by the complete double roof cornice, so that the difference between the upper surface and the section of the pinnacle obtained by this projection gives the width of the gutter, from which the water is ejected through beasts set diagonally. This difference of the surfaces would have remained useless, unless the pinnacle projected there and was thus corbelled out beyond the face of the buttress.

Conducting the water.

All the arrangements mentioned show a conducting of the water in the open air, and thus afford the advantage, that any stoppage is easily seen and removed. Conducting the water through the buttress on the contrary usually ensures the advantage of a shorter course. Such outlets are generally more perfect, since t they are larger and the bottom is maintained with the greatest certainty. The last purpose is best attained by overlapping slabs with drips in the direction of the water (Fig. 1066).

For high buttresses the parts above the thrust alone increase by their load the resistance. This condition is most clearly e expressed by extending the buttresses above the roof cornice, which then in the simplest case terminates with a gable roof, when the knob crowing the latter either is over the front or over both gables, or with an increased size can be placed over the middle of the ridge. This increase has its reason in that it concerns the bringing of the crowning into proportion to the length of the ridge, and in its greatest extent leads to p placing a great pinnacle.

Concerning the position of this part of the buttress it is to be stated, that if no stone gutter exists, a development of it from the roof causes certain difficulties in regard to the addition to the roof, which produces no good effect by direct contact of the smooth surface of the buttress, or that adorned by blind arches, with the rough surface of the roof, and this is better avoided, so that the roof cornice passes behind the rising buttress and even leaves a small interval between them.

By the principle of loading is given ammeans to reduce the other factors, the resistance of the buttress, thus the thickness and width of this cross section. This condition is then e expressed first in this, that the profile of the buttress again approaches the vertical, which is then broken by the different

offsets and their caps sometimes ornamenting only to a few inches.

As stated elsewhere, buttresses risinm tolerable vertical and quite strongly loaded above are in place, particularly where very high thrusts occur (p. 335). The upper loads at the same time afford the welcome opportunity to develop tall and gracefully tapering crownings, that in the course of time come into ever increasing use in the form of pinnacles.

4. Pinnacles.

Construction of Pinnacles according to rules of the old masters.

Chiefly in their connection with gables and tracery, pinnacles form a particularly prominent group of Gothic forms of development and in their extremely diversified forms and combinations substantially contribute to the richness of the whole, but like tracery extend almost to overloading. Thus were regarded from the 14 th century as given magnitudes, and as the common possession of all materials and trades, they were employed for almost every conceivable purpose. If then in the middle ages such exaggeration always occurred with skill and good luck, such is not to be praised in all modern applications.

Pinnacles according to Roriczer.

From the last times of the 15 th century the "little book of correct pinnacles" (Note) with an appendix on the construction of gables, which gives correct determinations of the dimensions of certain kinds of pinnacles, more ornamental and kept within smaller dimensions, that we shall follow here in an extract.

Note. By Matthes Roriczer, cathedral architect in Regensburg; Reichensperger, Vermischte Schriften.

In Fig. 1067 let a b be the square plinth of the pinnacle, t then are determined by the inscribed diagonal square the two squares next found, the plan c d of the shaft of the pinnacle and the bottom e f of the recesses formed therein. Then divide f g in 3 parts, lay off 2 of these to h, and thus is determined the quadrant struck from h with h g with its fillet forming the moulding of the body at the recess. Then describe the rectangle g g k k, so that k g = 2 g g, and thus determine the line l m drawn from l determines the projection of the crocket, whose plan is l m g g m. Likewise the distance between the two outside squares determines the projection of the gable cornice. From these results the elevation of the pinnacle as follows:- the height

of the body including plinth = 6 a b, that of the latter = a b, and that of the pinnacle = 7 a b as given in our Fig. By the same numbers, the upper width of the pinnacle = 2 h g on the plan. The ridge n of the gable is then 2/3 of the height from 6 to 8. Since then the extreme point of the projection a results from the plan, then the slope of the gable is a n and by o p parallel to the same is found the height of the gable cornice. The extension of the lower line of the cornice to the upper one, thus from o to p gives the width p p as the lower width of the stem, whose upper and middle is determined by h g of the plan. Further 8 q = f h on the plan, and the two squares q r s s are constructed on the middle line with the same sides, which gives the dimension of the knob crowning the stem.

The points 11 and 12 then give the upper edges of the moulding separating the pinnacle from the crossflower and the flower itself, whose projection is determined by the plan square a b and its height t u by 1/3 of the side a b. The distance between the two squares a b and c d in the plan further gives the width 13 v, while the widths v w and 11 x are determined by 2/3 of t u, as well as the height of the top knob and of the moulding under the flower. The projection of the knob results from the square e f in the plan, and that of the cornice by the square c d there, the under edge of the crockets are finally given by dividing the distance 6 @ into six parts, and their heights by the distance m m in plan.

By further execution of the form of the crocket then results the form of pinnacle given diagonally in combination and drawn in connection with the curved window gable. In the frequently mentioned Instruction of Lacher is found still different determinations of the heights of pinnacles besides those agreeing with those of Roriczer. According to one should the body of the pyramid have heights of 8 a b, a proportion that he calls the "fresh division", according to the other the body has 7 and the pyramid 8. But the use of such slender proportions he makes dependent on the goodness of the stone, and further whether the pinnacle shall stand in the drawing. But generally in Roriczer as in Lacher, it is recognized from the entire combination, that the given determinations relate to pinnacles and rather an ornamental function on buttresses adjoining or bonded to wall surfaces, and especially when combined with window gables and kept

within moderate dimensions, but not to thus more structural uses, that load the buttresses and terminate their forms.

Window gables according to Roriczer.

We shall here also follow the construction of window gables according to Roriczer.

The distance on certres of the pinnacles in Fig. 1067 b measures 6 a b. With c d circumscribed about the squara ab in Fig. 1067 c gives as e f on the centre c of the pinnacle set back as the angle and in the intersection with that likewise set diagonally the dimensions of the jamb and division of the mullion for the blind arhh or the window, which will be crowned by the gable. The profile of the latter then results from the equilateral triangle constructed with the side g h. By Roriczer this is developed in the manner shown in the side Fig. 1067 d, thus with a concave hood in plan, but a different form of corresponding elevation and a different basis with the corresponding form given at g h i. The line k k drawn through the end k of the hood gives the middle line of the normal square of the crossflower of the gable, whose outer square determining the plan of the 4 leaves l l in elevation coincides with c d. The second square n o gives the plan of the stem moulding n o in elevation, the third q rthat of the top knob q r, the fourth s t is that of the stem at s t above n o, and the last u v is the top plan of the stem. It is then to be noted that at top the square is changed to an octagon.

The height of the pinnacle then determines that of u v, thus the point of the crossflower on the gable, whose total height from u v to x is fixed at 1/8 the height of the pinnacle. The separate heights of these are given in exactly the same proportion as on the pinnacle, so that for the side of the outermost square a b there taken, the side l m enters here, etc. By the connection of the plan of the stem s t and u v and the extension of the lines concerned downward, results then the diminution of the stem of the flower, on whose border line will be tangent t the outer arch of the curve of the gable. Thelatter can be constructed as follows. First draw the plan of the gable, thus the profile g k i h in the plan of the pinnacle at the place from which it shall go, here then in the projection of the plinth of the pinnacle. Then strike the separate lines determined by the profile of the window arch from the assumed centre, here at

z in Fig. 1067 b and further by the separate concentric arch lines resulting from the gable profile. Then erect at the point x a line x y perpendicular to the diminishing line of the stem, and seek on the latter a centre, from which can be struck an arch tangent to the line of the stem and to the outer line of the arch, and accordingly strike thus concentric with this and the other arch lines of the gable. In a corresponding way, as given in the right half of our Fig. could be constructed an angular gable with straight lines. The projection of the leaves resting on the wash of the gable from the extreme corner of the profile, thus q r, and likewise their height n r, are determined according to the lengths on the plan similarly lettered, and the distribution of them on the outer arch of the gable is made.

Pinnacle according to Lacher.

That the construction developed above agrees in a way with t the examples given by Lacher, yet they only afford even a greater freedom.

What first concerns the proportion of the width of the whole, this is the distance between the pinnacles, it only requires that the distance between the pinnacles, "the width of the gable," will be determined by the side of the square of the plinth of the pinnacle, but it is left free whether this side shall be taken 8, 10 or 12 times for it. On the development of the elevation of the gable, whose principal divisions he gives to correspond to Roriczer's (Note), he derives the construction given in Fig. 1067 b of the arch lines from those of the stem, "when thou hast the stem of the gable, thou canst draw the arches therefrom; some gables have only a half circle, also some are higher." Since he now fixes the total height of the gable to the point x in Fig. 1067 b as 2/3 the height of the pinnacle, it follows f from this that the radius of the upper partof the arch causing the ogee curve is in an inverse proportion to that of the lower, and therefore with a straight course of the spandrel of the gable = 0. Of the crossflower he says further, that some need a great and a small flower, since it will indicate in the distance it will show as well also the knob, so that by thickening is to be made with the circle as a basis.

Value of these rules.

We remark that we have not given these rules of the masters dating from the latest times of Gothic here in the sense, that

the proportions obtained by them should be generally determinative. Such a claim was at least in the mind of their inventor, since then Lacher in particular gave this instruction to his son, only to cause him to learn the parts concerned and their forms, but emphasizing everywhere the greatest freedom in their application. And here might we generally restrict the true use of all such rules to this, that they give to beginners useful explanations, but nowise should form a criterion for the value of any other form. In reality almost every pinnacle according to its position requires a special development of its dimensions, and particular proportions. The most important and significant function of the pinnacle is that, from which we started, namely the loading and termination of the buttress. We must therefore seek to develop the leading idea of the entire form on it, and therefore show that in one case a stumpy form, in another case a more slender pinnacle is in place, thus the master's rules of the late period very soon refuse their service. As already stated, the rules appear to relate only to that time of everywhere springing and more ornamental pinnacles, which already results that they appear to have been conceived as made of a single stone. When several blocks are in question, there occur other conditions, as on an example represented in Fig. 1068 might be explained in regard to the projection of the crowning.

For the side length a b (Fig. 1068), let 75 cm be assumed as an ordinary thickness of the pier for moderate dimensions, and the height of the pyramid a b 4 may be laid off as 4 times the base. Hence the total height of the pinnacle will amount to 3 m, and it will also be composed of several blocks. If the available thickness of the stone is 40 cm, and if the top of the pyramid is a stone set on end, then as c d e f shows, that would not make up half the height if the projections of the bosses still remain in it. The upper knob is also naturally included within these limits, so that projections such as Roriczer gives for t them are evidently forbidden.

In our Fig. 1068 the crowning consists of the stem supported from the pinnacle by a moulding g h, the stem and the roll knob, and the height of this part is obtained according to the division in 5 parts frequently given by Lacher, the projections as noted by the width c d, the lower thickness of the stem by extending the outline of the pinnacle to g h.

Different forms will result by raising the moulding on the s stem about one fifth, or by simplifying or by omitting the stem moulding (Fig. 1068 d).

Crowning of the pinnacle.

Necessity for the crowning.

Cutting the upper block into the sharp terminal point of the pyramid is hindered by the nature of the material; but the assumption of a frustum of a pyramid gives an imperfect form and therefore is opposed to the conception of a termination; Hence it is necessary to find the form of a crowning fulfilling those conditions. The need for crowning all points existing in the u unity as one so common to all architectural periods, that it can pass almost for an innate idea. Thus is found the crowning of the apex point on the pagodas of the Hindoos, the towers of the Chinese and the pyramidal works of western Asians. So the Greeks crownedthe pediments of their temples and ridges with the figures of the gods or with acroterias and facing tiles. T Thus the dome requires its crowning, although the pole is here only a point given by the position and not by the peculiarity of the body, in the measure that it usually acquires a definite expression. It is proved by the high domes of the Renaissance compared to the Roman composed of circular segments. The form of the crowning varies with that of the body, and the ridge of the roof requires a continuous cresting, the dome a concentric one and thus a crown or cone, but the pyramid and cone demand a culminating form, thus the stem with the bud, flower and crest.

Hence it is a need of an antiquity unknown to us, for the carpenters to place the bush on the ridge of the completed frame of the roof, the cresting as a true acroteria, thereby indicating the time of completion. Now the varied forms of points and gable crownings of Gothic art, what are they other than permanent indications of that time, then the crest in the stone style. In spite of the so common designation of these crownings as crossflowers, the cross has nothing to do with them, and it is found far more frequently even placed above them, usually standing where the ancients had placed a cross, which they could and did publicly, and in fact had in a sense excluded a completion.

Projection of the crowning.

Now returning to our Fig. 1068, there is determined as we have seen, the side c d as the dimension of the ashlar and as the pr-

projection of the crowning. We do not maintain that this proportion as well as all determinations of the details should follow the dimensions of the stone with mathematical accuracy, and just in this case the reason for exceeding the width c d will appear later. But from considering the dimensions of the stone result two points especially important for the form of the pinnacle.

1. That the magnitude of the crowning does not increase or diminish in exact proportion to the pinnacle, that rather a considerable size of the pinnacle requires a proportionally smaller crowning.

2. That certain projections of the pinnacle correspond to each other, since the projecting parts are inscribed in the form of bosses.

In regard to the point first mentioned we refer to the pinnacles of greater dimensions represented in Figs. 1068, 1072 to 1077 in contrast to those of Roriczer and the metal pinnacle given in Fig. 1070 from the tabernacle in S. Maria at Lübeck. As in Fig. 1068 the combination of several blocks requires a smaller dimension of the crowning, so in Fig. 1069 the low location of the joint a b above the gable terminal leads to an agreement of the crown with the thickness of the pyramid or body, and in Roriczer the form of the entire pinnacle of one stone l leads to an agreement of the crown with the plinth, and generally with the greatest projection occurring on the pinnacle. But that in those rules of the masters is assumed the construction of the entire pinnacle of only one stone, occurs several times in Lacher. Page 144 states:- "And divide the same thickness of the stone into 16 parts; of the same parts make a square as large as the body of the pinnacle."

Thus in Fig. 1070 the art of metal working allows entire freedom from such restrictions, and therefore a crown beyond any dimension of the pinnacle.

Without this flexibility of proportions would the actual dimensions become entirely obscure, and further in certain cases complete deformations would occur. Such would result from an attempt to construct a buttress according to that of the Friedberg church about as shown in Fig. 1074, a pinnacle developed after Roriczer's system, or one of the pinnacles given in Figs. 1068, 1072 to 1077 with a crown constructed according to this system, or in the converse sense by the application of the proportions

developed in Fig. 1068 from the form in Fig. 1067 b.

Yet we note here also, that likewise the different periods in relation to the projections, first those of the crowning were very heavy, and that in the earlier men certainly rightly gave preference to a smaller projection even on smaller pinnacles, as this is shown by a comparison of Roriczer's pinnacles with this from the Freiburg tower perhaps 150 years earlier (Fig. 1069).

Height of crowning.

The highest point of the knob can lie just at the apex of the pyramid (Figs. 1068, 1065, from the choir of the church at Gladbach) or by lower (Fig. 1068 du. In the last case even when it is quite condensed, it lends the pinnacle a slender amd aspiring character (Fig. 1072). A termination of the crowning even below the apex of the pyramid on the contrary can only satisfy the eye if that is extremely slender in form as in the examples of Figs. 1070, 1071. Most commonly must the starting of the crowning be above the apex of the pyramid, especially if the latter has the form of a crossflower, then the apex of the pyramid usually coincides with an evident division of the height. Examples are g given by Fig. 1072, 1074, 1077, in regard to the upper finial (while the lower has a shortened point).

While on the finials and pinnacles of S. Chapelle at Paris (Fig. 1072), the proportions of the pyramid are about 1 : 3 1/2, those of the entire height of the crown are about 1 : 4, and the division point 3 normally at the top of the moulding of the stem, the finials and pinnacles of the Friedburg buttresses (Fig. 1074) in the pyramid itself, thus from a to b has the ratio 1 : 5, the point 4 gives the bottom of the moulding of the stem and the total height of the crowning is determined according to the diagonal of a side of the base.

As already stated concerning the crownings of the gables, in general is to be preferred the octagonal section of the knob to the square one, particularly in simple forms, and accordingly the stem is chamfered so that by means of dimeosioning, the width of the chamfer becomes a regular side of the octagon under the knob. The transition to the rectangular angle is then effected either in the stem itself, or in the moulding joining this to the pyramid or in the latter (x in Fig. 1074).

Pyramid and body of pinnacle.

According to the simplest and easiest way, the pyramid is placed on the body above a horizontal cap terminating it, whereby either the base of the pyramid is determined by a projection of this moulding, which then has the effect of a member of the lower border (Fig. 1076), or the base of the pyramid coincides with that of the body, and therefore the cap projects above and belou. (Fig. 1068).

In most cases a horizontal separation between pyramid and body is lessened, and an intersection of both is found by the arrangement of gable roofs on four sides of the pyramid, at the same time discharging the rainwater diagonally. In our Fig. 1068 the height of this gable is 1/4 the height of the pyramid.

Square pyramid. Leaf crockets.

The angles of the pyramid remain plain only in a very simple form (Fig. 1075) or they are treated with a projecting round. As a rule they are beset with little-flowers, the so-called leaf crockets, which give the principal outlines a more definite expression, and at the same time by their number make the size of the pyramid more apparent. On the older works may also be recognized the execution of a fixed principla, whereby the number directly depends in the size of the pyramid, and the width and size of the crockets would be constant like the converse proportion, and thus there is a constant number and a proportion of the size of the crockets to those of the pyramid. As a rule the number of crockets varies from 7 to 12, but increases to 17 on the great shrines of the cathedral of Rheims, and the little pinnacles from the tomb of Ulrich von Lichtenberg in Strasburg minster even to 26, but on the contrary on certain great pinnacles on late French works it sinks to 3 or 4 (Fig.1071).

Equal sizes of crockets on pyramids of unequal heights are sometimes required by the connection of these together (as in Fig. 1077). Generally in the later time the number of crockets is reduced and their size increased.

For the divisions of them to correspond to the bed joints, w which must lie between the crockets, as a necessity of construction.

As a rule the distances apart of the crockets equals that of the upper one from the moulding of the stem as assumed in Fig. 1068. But sometimes the last space is wider, and preferably so, if within it is made the transition of the stem into the octagon.

The projection of the crockets is generally reduced with an

increase in their number, yet there is found here no distanct relation. But on the character of the entire pyramid the closer or wider spacing exerts a great influence, as can first be proved by comparing Figs. 1069 and 1071. More details on the separate forms follows farther below. In Figs 1068 and 1068 b we assume the well known horn-like shape from the shape of the capital and enclose this by two incisions parallel to the sides of the pyramid.

The crockets either grow directly out of the angles of the pyramid (as in Fig. 1068) or a continuity of them can be produced by ribs which strengthen the angles and either stop on that horizontal moulding or the intersecting gables, or are corbelled out above them. The mouldings are to be of simple form and consist of a round, that may also be strengthened by a ridge or by a rectangular fillet projecting from the surface of the pyramid. These ribs either unite under the moulding of the stem (as in Fig. 1072), or then turn out the end at a square corner as in Fig. 1068, in the first case the section of the pnramid beneath the stem moulding gives a ground form of the square, which is then surrounded concentrically by that moulding, so that either in the last is made the transition to the octagonal stem, or the stem retains the ground form of the pyramid (Fig. 1073). A connection of the crockets together also results in a converse sense, in that the octagonal form of the stem continues in the manner, that the sides of the octagon lying in the diagonal direction extend downward as chamfers in the same width on the angles of the pyramid (Fig. 1079), and either stop on the gables or t the lower crocket, or below pass into the rectangular form by a transition.

Polygonal pyramids.

Entirely different from these chamfered forms is the shape of the finial of an octagonal pyramid, to be preferred in greater dimensions. Here result eight equal angles and therefore likewise eight ribs adorned by crockets. However such forms rather belong to forms of towers, and therefore become particular transitions from the square to the octagon and find their explanations there. As preliminary we mention here only the very peculiar pinnacles of the Early Gothic period, in which each of the four different surfaces between the square and the octagon forms the half of the basis of a smaller pyramid of a pinnacle, which

in its other half grows with the great pyramid and will become free in the development of the height. Fig. 1077 exhibits such a form from the west front of the cathedral of Rheims. Here the surfaces of all pyramids extend to the extreme edge of the projection of the moulding, so that the rib accompanying the angle of the pyramid is corbelled out, or rather stops at the foot of the pyramid on a beast leaning outward. A further enrichment is sometimes formed by a gable, that lies before the middle surfaces of the great pyramid, and thus is flanked by the little pyramids.

Finials of cross-shaped form.

A very peculiar transformatio of the octagonal ground form of the pyramid into the cross form is shown in Fig. 1081 representing the pinnacle from the buttresses of the cathedral of Besancon. On the squares remaining below between the arms of the cross are again placed smaller pyramids, and as the plan in Fig. 1081 a shows, they are divided by a moulding projecting in the crockets, which terminates with the last crocket, so that the simple cross form remains above. Since this moulding entirely covers the front surface, then exists the need for dimensioning it upward, that again includes a proportional reduction of the crockets and their distances apart. The ground form of the cross then continues in the crowning in the way, that the fronts form heraldic lilies, whose contours are then wrought, so that a similar intersection arises as that between two gable roofs. The entire treatment brings with it, that the pyramid only has a stumpy expression, from which certainly results a squatty and heavy effect. If then it is not to be denied that here peculiarity dominates beauty, yet these forms of the earlw time are especially instructive, compared with those of the 14 th century controlled by the monotony of the pinnacle forms, in which men are accustomed to see the highest development. It may be that the forms of the latter period, with especially the types of Cologne cathedral afford unsurpassed models for all in smaller dimensions, then will everywhere be allowable to strive for greater diversity, where it concerns a development of them in greater dimensions. But the motives there lying as a basis are connected with the construction of the spires of towers, and therefore here we must refer to the Section of our work treating the latter.

Triangular pyramid.

Also the equilateral triangle can be taken as a basis for the pyramid, and then by chamfering the angles it first passes into the irregular hexagon. A particularly thoughtful solution of t this kind is found on the pyramids of the pinnacles of the high altar of S. Elisabeth in Marburg, which rest on the gables terminating the body according to the ground form shown in perspective in Fig. 1080, so that the angles of the triangular pyramid are chamfered by the surfaces b c and c d in the direction of the sides of the regular hexagon, and the side surfaces of the pyramid assume a concave form. By means of the diminution of t the pyramid then the chamfers combine higher at e, and there results the form of the regular hexagon continued in the stem.

The pyramid developed from the triangle first requires a similar ground form of the body, yet may also be connected in a different manner with the square or rectangular form of the latter. The side surfaces may then be ornamented by the frequently mentioned scale work as in Fig. 1072, in greater dimensions by tracery as in Fig. 1077, and finally the pyramids may also be perforated, for which Fig. 1088 presents the simplest motive.

Body of the pinnacle.

What concerns the body of the pinnacle is its mode of treatment, the method of terminating all above the buttress and to apply what is said concerning blind panels. For the proportions of the height were already given on p. 459 and 460 the determinations of Roriczer and of Lacher, that certainly for greater dimensions and structural functions of the pinnacles would no longer remain usubla, but are to be developed from the latter. If a harmony of the ground areas of pyramid and body lies nearest, so that both separating horizontal or gable cross sections project above and below, it is evident on certain works, particularly of the early time, that to increase the expression of the loading thereby, so that the extreme edge of that moulding limits the base of the pyramid, as in Figs. 1076 and 1077. Conversely the effect will be lighter by reducing the base of the pyramid from that of the body, whereby the former may assume a slendered proportion of height even exceeding that of Roriczer. By such slender forms then, as already the case in Figs. 1067 and 1069, there is excluded the possibility of completing the pyramid, the stem of the crowning continues the diminution of

the latter in a changed direction, and therefore differs in the earlier examples as in Fig. 1069, still by the greater height and the contrast of its simple angles from the pyramids with their subject crockets; but this separation lessens in the degree that the crockets are spaced further apart, and so there results a transition to that pyramid of the pinnical chiefly peculiar to the French Late Gothic, which is beset by widely distant and strongly projecting basses, and is terminated by a simple knob (Fig. 1071).

Simplified and combined forms of pinnacles.

Simplified pinnacles.

Simplified forms of pinnacles result when on the capitals of the angle columns dividing the body, besides blind enclosing arches also the ribs of the angles of the pyramid and the beginnings of the gable cornice rest on them, or if the gable is replaced by a projecting moulding concentric with the arches, or finally, when the arches directly intersect the pyramid, and thus in their thickness establish the transition between the inclined surface of the latter and the vertical surface forming the ground of the blind panel (Fig. 1064).

Richer pinnacles.

Conversely result more complex forms, first according ho the principle which lies at the ground of the spires of shrines at Rheims (Fig. 1077). First its form suffers the transition that the four angle pyramids are replaces by angle pinnacles, and thereby is made easier the placing them over the horizontal ending suppressing the gable. Thereby will further be avoided the need of crockets of equal size on the great central pyramid and the smaller ones of the angle pyramids, since thus no longer come into contact with each other. Yet there is not now found an accurate observance of the proportion of the crockets to the different sizes of the pyramids, but rather a middle course is followed. Then the middle pyramid is a regular or diagonally p placed octagon, the diagonal of a square, or one placed parallel to the body, and likewise the little angle pinnacles are parallel to the diagonal of the great one. The lower pinnacle in Fig. 1077 shows an example of this kind.

The termination of the body of the pinnacle may receive a richer form, if the horizontal terminal moulding either passes above the gable as in Fig. 1088, or intersects the gable at the

height of the crown of the arch. In both cases with greater dimensions this cornice can have a tracery balustrade and angle pinnacles rising above the latter, which either stand directly on the gables or on the horizontal cornice. The great pinnacle from the end of the choir of the cathedral in Paris exhibits such a form. In the later periods the buttress evermore tended to express verticalism more decidedly, therefore to place the angle pinnacles on the capitals of the angle columns, which were then added to the jamb columnsof the arched members. Acordingly the gable cornice intersects the angle pinnacles or extends on their bases, or if these are wanting, on the projection of the capital of the column, and then each side of the pinnacle shows the completely developed stem of the form of the window gable bordered by little pinnacles, hence a reproduction of the whole at a smaller scale.

This system of ornamenting the smaller parts with the tapered principal form is especially characteristic of the middle and later periods of Gothic art and includes the possibility of an endless multiplication, so far as for example those angle pinnacles could again be formed according to the scheme of the larger, etc., until the conditions of the execution put an end to the principal infinity.

The use of reproduction in the development of height then led to placing on the body of the first pinnacle a second of smaller cross section, on this a third, etc. only crowning the last by a pyramid. Also there results by a similar arrangement the transformation of the pyhamidal finial into a stepped form in a series of prismatic bodies, and a lessening of the difference between finial and body, thus also here again by the diversity only of increasing monotony. This would go one step farther, when such a compound pinnacle was set on a buttress, and the offsets of the buttress likewise received pinnacles of like form.

That such a sequence must be subject to certain laws in order not to lead to monstrosities, will come from the following consideration:- if we take Roriczer's proportions as a basis, the first body would have a height of 6 sides. Assuming that the side of the second was reduced about 1/6, this would be 5 sides of the first in height. Assuming the third to be again reduced by 1/6, then it would be 4 sides and the pyramid terminating it is 2 3/3 sides high, and hence the entire form would approximate

the ratio of 1 : 20 instead of Roriczer's very slender one of 1 : 13. By reducing the offsets 1/10, there would result for the same case the proportion of height of 1 : 22, and therefore an unlimited height according to the degree in which the sections of the bodies approach each other. Therefore either the offset of each successive division or the proportion of the height of the whole be controlled to limit that increase in height.

Hence in Lacher (Reichensperger, p. 144) is found concerning the form of such compound tabernacles (which this is) the decision, that the second tabernacle, i.e., the second body of the pinnacle is to be formed according to the second square of the first formed quadrature, whereby its side would be about 7/10 of the first one; likewise the third according to the third square. We now accordingly calculate the height of the entire form and this will have the proportion of 1 : 16.5. Here we have indeed taken Roriczer's proportions quite arbitrarily as a basis, since Lacher gives no determination of the heightof the whole.A development in height would be found as follows:- In Fig. 1082 let the rectangle a b c d be the body of the pinnacle, then we assume the proportion of the height that shall be the sum of t the parts placed on each other (for example that about a simple pinnacle finial measures 1 : 6), and construct accordingly the pyramid c d e, that includes the otherwise freely chosen separate offsets f g h i, k l m n, and thus also the pyramid m n e of the latter. Thereby results in each division a reversed proportion of this height to the breadth.

When the smaller offsets of the body of the pinnacle (like t the second in Fig. 1082) a reduced proportion is obtained, then by reproduction of the blind paneling or by the assumption of a polygonal section, this will be partially raised as in Fig. 1083.

Thereby this scheme may be combined with the before mentioned insertion of the plans within each other by Lacher, that indeed of itself results by the diagonal position of the bodies of the pinnacle set on each other.

As in Fig. 1081 is found a cross shaped form of the finial i instead of octagonal, so occurs the cross form also in the offsets, and it can here exert an influence on the richness of the elevation, so far as thereby results the development of 4 pyramids, from which rises the crowning terminal pyramid.

Everything said here on the development from the square is

likewise true for that from the triangle.

Conncetion of the pinnacle with the buttress.

The pinnacle may form the termination or an offset of the buttress or by a greater height of the body man make the predominant part of the entire buttress.

Pinnacles above the roof cornice.

The first horizontal termination occurs if the pinnacle stands on the roof cornice broken around the buttress. Here the dimensions of both parts may accord, or the pinnacle may be reduced so much that on the increased projection of the cornice the gutter mentioned on p 457 may find a place. The pinnacle then appears in connection with the balustrade, or so that the beginning of the latter may be wrought on it (Fig. 1098), or the part of the balustrade is inserted in the body of the pinnacle in a way like the tracery in the window arch, or finally if the pinnacle projects farther so that the connecting walls of the balustrade join the rear side of the pinnacle. The entire proportion of the balustrade then first leads to determine the height of the body according to the height of the balustrade, whereby this in ordinary dimensions has about the proportion of 1 : 1, or that of the side to the diagonal of the square. According to the form that the pinnacle must have, either the cap of the balustrade is to be broken around it (Fig. 1068), or the top of it is to be taken as a base of the arch terminating the panel (Fig. 1085). From this determination of the height indeed are found variations toward both sides; thus on the pinnacles of the S. Chapelle in Paris the base of the gable is found beneath the cap crowning the balustrade, while on most later works the endeavor to carry the height of the pinnacle above that of the gables crowning t the windows, or at least to attain the same height first permits a slendered form of the body of the pinnacle, so that its termination is raised far above that cap of the balustrade, as on Cologne cathedral.

Pinnacle on the covering of the buttress.

But the placing of the pinnacle on the horizontal surface formed by the crowning cornice requires an approximate agreement of the size with that of the buttress. Greater freedom occurs if the buttress terminates with an actual roof, on which then the pinnacle is either set considerably reduced or diagonally, or is placed on an area differing in form (Fig. 1076), so that

the difference is formed by the roof. Richer forms further result by the combination of the middle pinnacle with smaller angle pinnacles set on that difference in area. Thus on the choir buttresses of S. Ouen in Rouen, octagonal middle piers with two smaller angle pinnacles are set on the front side, a and on the latter on account of its smaller size, the pyramid is replaced by a simple low pyramidal roof. Preferable are the buttresses of the upper octagonal story of the tower, that afford opportunity for the same arrangement. So the buttresses in form of a diagonal square on the Freiburg tower, one is set on the diagonal middle pinnacle with 3 angle pinnacles, one of them is over the angle of the buttress, but the other two stand on the cap of the balustrade, while the fourth inside is omitted.

Further the pinnacles of the cap of the buttress beneath the roof cornice stand as in Fig. 1076, or already appear with the body in combination with the latter, as on the church at Friedberg (Fig. 1074). For smaller dimensions it is next to place the pinnacle at the point of application of the vault thrust on the offset of the buttress, whereby its body can always reach the height of the cap of the balustrade, that accordigly acquires an important proportion of height exceediug that of the pyramid. Thus the pinnacle can either stand free and connect with the roof cornice and the balustrade only by the spout, or even with the wall by a thin wall.

Pinnacle on an offset of the buttress.

The offsets of the buttress can receive pinnacles in the same way as the upper caps, or these may be made with a compound form of pinnacle, which then in a richer form already begins above the cap moulding and forms the predominant part of the buttress. This overrich form is chiefly peculiar to the later periods of Gothic art, and then by the use of placing diagonally, by artificial penetrations, by combination of solid with hollow pinnacles, i.e., shrines and figures, by the use of canopies and of the pedestals usually supporting the figures, quite charming forms are designed. Particularly in upper Saxony, on the choir of the church at Freiburg-on-Unstrut, on the city church at Naumburg, are found such forms. Yet it is to be noted, that even the accessories mentioned, the use of figures, the alternation of solid with hollow forms, etc., is here entirely necessary for good effect, and that the mere combinations of pinnacles, were they arranged according to

such an artificial scheme, yet easily produce a certain dryness, and that particularly by an excessive division of such forms of terminal pinnacles is easily caused an apparent vanishing, indeed in such a striking manner, if between the buttresses and the windows remain considerable wall surfaces. Really there is not easily found a more striking contrast, than that between the effect of these later works and those of the Early Gothic even if richly adorned, on which the entirely simple buttresses, and rich and graceful forms of windows, in which the wall surface dissolves, included between them.

5. Gables and Window Gables.

Coping and crowning the gables.

The simplest covering of the gable occurs when the roof covering exte ds over the gaple wall, so that as for a wooden gable, the thickness of the tiles or slabes laid on each other forms the upper termination of the gable wall, and makes a small projection for its front face. But these projecting edges are exposed to the effect of the wind in a high degree, by which may be caused the raising and tearing away of some pieces. For protection from these effects, to shelter the roof from t the wind, there is found on carefully executed works an extension of the gable wall above the junction of the roof, which as a rule is effected by a pediment with a coping at top.

Development of the edge of the gable.

Further to protect the junction of the roof at the inner side of this raised coping, thus the joint from the penetration of rainwater, every coping has here an undercut profile, a cut drip beneath which the covering of the roof lies, rising a little toward the coping. Fig. 1084 shows such a gable, where the upper moulding with its drip rises a little above the surface of the roof and forms a wind protection or gable, as shown by the cross section a b in Fig. 1084 a. 'Besides the proper name of "wimperge" is common that of "wimperg"; both names are employed for the coping and also for the little gable, especially when built over the window arch).

The separate cut stones of the coping stand best if bonded with the gable masonry, whereby according to the inclination of the gable and the nature of the stone, the bed joints are made horizontal as in the left half of Fig. 1084, or are perpendicular to the line of the gable as in the right half.

The thickness a b in Fig. 1084 a under the projecting coping must only be sufficient to afford a secure bearing of the separate stones on the gable wall, and need not agree with that of the wall, while a part of the latter extends under the roof covering, indeed so that for greater thickness a rafter lies on it. Richer arrangements result when on this excess in the thickness of the gable wall are formed steps leading to the highest point of the gable, and forming a communication between the two eaves of the roof. In this case the steps lie so much above the roof surface, that this drip x can be cut in t their lower edges, and the stairs is made safe by a parapet o outside, which either man take the form of a tracery balustrade, as on the church of S. Lorenz in Nuremburg, on the city hall at Louvain, etc., or the simpler form of the window gable.

If we now return to Fig. 1084 a, then the width a b also expresses at top the surface forming the back of the gable, so that the washes only extend on the projecting cap (Fig. 1084 b), or may be entirely omitted (Fig. 1084 c), or finally as in Fig. 1084 a the washes extend from both edges for the entire width and meet in an angle at the middle, which with a steeper inclination of the wash results a strengthening of the ridge of the gable. Fig. 1084 d shows the elevation and Fig. 1084 e is the plan of a stone of the coping.

Crockets and stepped gable.

From the originally rectangular shape of the block a b c d results the motive of the crocket projecting from the edge of the coping, just as it gives opportunity for the form of stepped gable more commonly occurring on works of secular architecture. Accordingly with equal sizes of the blocks each one has a crocket or forms a step. Gables of the last kind are now f found in different places. Thus as the latter motive developed from the origin leads to the arrangement of larger steps consisting of several ashlars, so the endeavor for freedom from the restriction caused by the size of the stones led to inserting the crockets in the back of the coping, or to form them with tongue and groove as in Fig. 1085 c. But nowise was the form of the crockets in the mass of the ashlars entirely supplanted by the last construction.

Crowning the gable.

The crockets extend to the middle to form the stem of the

Crowning of the gable, so that with the rib connecting the crockets either strikes the middle of the stem, or rises upward in the last two crockets; accordingly it lies close to the stem, and like the corresponding part of the rib itself, and if the former is inserted in the length of the side of the gable, must still be made in the same stone with the stem, which then receives tha form given in Fig. 1084 f. From the size of this ashlar and the width m n accordingly results the determination of the magnitude of the crowning, that canno be in direct proportion to the size of the gable. If the breadth m n is too large, then the projection of the crowning is better determined by the thickness of the gable, thus according to the width x in Fig. 1084 a. Then if it eppears preferable in certain cases to increase the importance of the crowning with the size of the gable, it is in the nature of the matter more suitable to seek this by an increase in height, by the choice of the form within those limiting projectiins than by an excessive projection.

Such massive crownings result from placing a simple finial on the apex of the gable, as on the portal of the north transept of the cathedral in Chalons, where the body is further indicated also by the four gables terminating it, or passes to a more complete development and thereby may receive a superior treatment and a greater thickness, that corresponds to the entire thickness of the gable wall, and therefore projects into the roof over the inner side of the gable.

Greater heights of the crowning further result from their connection with figures or animal forms, which either may be placed on the moulding or the stem or on its terminal knob.

Gable cross.

Greater projections are easily possible, when sought in mere development of width, and lead to the form of crowning by a s slab, and hence first to the form of the crowning cross. But before all the latter requires a certain size, which increases with the base of the gable, even if not in direct proportion to it.

We cannot here refer to measures of mediaeval works but only to modern experiments, and accordingly state that on a gable with a base of 8½ ft. a cross measuring 7 ft. from point to p point is entirely a mistake, while another of 3 7/8 ft over a

base of 24 ft. produces a sufficient effect. Thus in general it is a peculiar appearance with a vertical stem, that develops to a slightly projecting form of crowning, will give a suggestive proportion by the addition of a horizal bar becomes p puerile. Further it is to be considered in the form of the cross, that the horizontal bar seems larger at the height than the v verticalcone, and hence requires a reduction in comparison with the size of the latter. This reduction then occurs by a tapering of the vertical stem upwards, so that the horizontal shall have the same size as the former at the intersection and also tapers to its ends.

Accordingly for greater dimensions the required length of the arms of the cross may exceed the dimensions to be obtained from one slab. In the case there remains the combination of three stone beams, so that the horizontal bar balances on the lower arm of the cross and the upper arm is set thereon. The same construction may also be employed on the so=called crossflower, and there leads to the form of a leaf cross from a slab lying on the stem, or of two overlapping stone bars. The entirely engaged character of this construction is quite foreign to the nature of the stone and plainly shows, that it is better to avoid all forms requiring it. The stem of the crowning then goes with the gable cap on the ridge, either with a penetration, oh it there occurs a transition of the ground forms into each other. Fig. 1050 a, b, ehibits an arrangement of this kind.

Pinnacles with stepped gables.

Just as pinnacles produce the crownings of gables, so also the angle flowers may replace them, when there remain additions from the mass of the ashlars. Here appears the analogy with the before mentioned form of greater gable steps. Sumh arrangements are even found on greater gables, as on the western one of the Teyn church in Prague, as well as on portal gables. We mention here the west portal of the cathedrals of Strasburg and of Cologne, and of the collegiate church at Colmar. On the work first mentioned is obtained thereby a greater magnipicence, that the pinnacles alternate with figures standing on low small columns. Yet it cannot be denied, that first of all the crockets closely set strengthen the impression of the gable slopes, such positions of pinnacles go beyond this and lead the effect into that of vertical developments. Thus the expression of the

inclination of the gable entirely disappears when the pinnacles extend down over the surface of the triangular gable, so that the latter seems lost in a certain number of adjacent panels crowned by ornamenta, gables, all of a predominant vertical character.

Beginnings of gables.

In regard to the relations which the gable coping at the lower ends of the gable have to the horizontal cornice of the longer sides, there applies substantially everything said of the gables of buttresses (Figs. 1037 to 1049). Meantime some modifications can be permitted by the special conditions. In Fig. 1084 c d is the line of the roof, and the profile of the gutter at its base is indicated by dotted lines. Accordingly the latter as well as the roof cornice in the front view of the gable either shows its profile as in the left half of the Fig., or the gable wall in the thickness of the gable below the gutter projects on a corbel, and thereby that profile is concealed. But the horizontal course of the gable cap e f assumes a greater length, and the load in it lies higher, if the edge of the gutter has a balustrade, as in the right half of Fig. 1084 (also see Fig. 1084 g). This horizontal course of the gable cap is fulfilled also if the inclined gable cap, instead of being bonded with the wall, consists of ashlars laid on it with the further purpose if opposing and abutting all the thrusts of thens blocks. Fig. 1084 g shows the side elevation in which at a the gable cap shows its profile, and thus assumes the form of a gable of a buttress, therefore all stated above concerning the latter also finds its place here. From the simple gable crowning as shown by Fig. 1084 g may further be developed a complete pinnacle pyramid, and further also the part of the wall beneath it with blind panels in the form of the body of the pinnacle, or even be changed into the form of a shrine. Also the pinnacle may, or even the simpler form of crowning, be transferred from the angle to the middle of that horizontal length, and thereby would a more important size be required, since this would be in relation to the entire length and no longer to the little gable a in Fig. 1084 g. Yet more massive becomes the covering of the gable by placing an entire pinnacle on that horizontal piece of coping. But the most complete form results of the gable is flanked fy the pinnacles set on

the buttress or even by angle turrets.

Purpose and connections with the wall.

The so extremely advantageous arrangement of the extension of the gable between fixed and independent buttresses termioating in pinnacles results of itself in the window gables characterizing the richer style of Gothic art. By Viollet-le-Duc the origin of this arrangement is explained by the necessity for aiding by loading, increasing the strength of the window arch, that had to resist the thrust of certain compartment courses extending from the crown. On the static importance importance of the window gable see p. 342. As an intermediate member might have the motive fulfilling the desired purpose in the nearest way, might be inserted here a strengthening of the window arch by a concentric arch turned between the buttresses, that for its special purpose required a separate covering, and indeed the gable form suited to that of the pointed arch. Also as shown by Fig. 1085, while the proper window arch a supports the upper wall with gutter and balustrade, so this strengthening arch b bears the thickness of the gable wall covered by the window gable, which may be constructed in a different way. As in Fig. 1085 a the section through the crown shows, the thickness of the wall stands as far as the u upper edge of the roof cornice in connection with the masonry erected on the proper window arch, so that the separate ashlars of the window gable are bonded, and hence the block c in Fig. 1085 receives the shape represented in perspective in Fig. 1 1085 b. Above the roof cornice the gable wall and balustrade then stand beside each other without connection, as shown by the section in Fig. 1085 a.

Conducting the water.

But by this mode of arrangement the removal of the water falling on the projection of the window gable, and therefore either the continuation of its wash to the face of the wall, or the arrangement of a gutter on its back is required. The first design is to be assumed about in the form shown in Fig. 1085 g, while the latter is generally followed as seen by the section on x y in Fig. 1085, shown in perspective in Fig.1085 d. At the base of the window gable, where it rests on the buttress is then found a gargoyle, that is connected with the channel.

Crockets.

In Fig. 1085 we have the working of the crockets assumed in the blocks of the window gable. The restrictions resulting from such a construction concerning the arrangement of the bed joints consist in this, that those resulting from the form of the roof cornice also pass through the window gable, and on the latter a crocket is formed on each block, indeed can be avoided by a more complex form of the separate blocks, most easily by an insertion of the tongue of the crocket in the back of the window gable as shown in Fig. 1085 c. This free position of the edge flower then affords the further advantage of facilitating the replacing of those injured by new noes.

Perforated window gables.

For a more animated and clearer form of the entire arrangement is further of great importance a perforation of the gable wall, as shown in Fig. 1085 at g. But also here in reference to bonding with the wall and the gutter lying at the base of the roof, as well as particularly the stonecutting in general, certain precautions are to be found, and first of all to avoid end joints lying in the face of the wall. A form suited to Fig. 1085 for the ashlars g and h is represented in Figs. 1085 e and f. But this changes according to the length of the perforation. If the last lies higher, then would the ashlar with the channel either extend through the entire thickness of the gable or an end joint could be placed within the perforation. But if the perforation were omitted, then would it suffice to let the stone of the channel a short distance into the thickness of the gable.

A further extension of this isolation then leads to making the gables and their crowning window gables entirely free before the masonry at the back of that projecting gable, so that there still remains space for the water channel behind, which accordingly instead of following the line of the gable as in Fig. 1085, has a course concentric with the window arch between the face of the wall and the gable wall. But this isolation of the gable wall leads further to its complete opening in a tracery scheme. Thereby in constructive respects it differs no more from the form of the tracery of the upper window arch, and joins the separate blocks of the window gable just as the latter those of the window arch; behind the gable then extends through the roof cornice with the balustrade and becomes visi-

visible through the openings.

This construction occurring at Cologne cathedral requires greater dimensions, and in smalles ones where it is already d difficult to obtain room for the beams and the channel with balustrade requiring a constant breadth, demands an exaggerated projection of the window arch. There is sometimes found a combinatiou of the roof cor nice with the tracery filling the gable, so that the latter directly joins the face of the wall, the roof cornice intersects it and a part of the members of the window gable, and thus divides the tracery form of gable.

But thereby that transformation of the entire design is entirely justified, which is found on the choir of the church S. Maria in Mühlhausen, and consists on this, that the triangular gable is entirely formed of open tracery, rests on the roof cornice and replaces the balustrade.

Inclination of the gable.

The proportions of the inclination are still relatively low in the older examples and the entire height is small. On the window gables of S. Chapelle the ratio of base to height is a about as the side of the square to its half diagonal, and only the crowning rises above the edge of the gallery. With the lesser width of some gables, such as occur on the choir polygon, it was next to assume steeper inclinations, which usually predominate in Germany, so that about the ratio of 1 : 1 results. Generally the pinnacle rises from the apex of the crown of the window gable.

Ornamental gable of the tabernacle.

In the measure that the thickness of the gable wall diminishes, the originally structural importance of the window gable is lessened, is expressed only in the parts rising above the horizontal termination of the wall, and it disappears entirely when its entire height joins the vertical face of a wall. Then it can still strengthen it about like projecting tracery, and yet especially attains ornamental importance and becomes a simple form of crowning or of subdivision. In this sense it finds a particularly common use on the simpler tabernacles and repositories, that from the 1 th century onward in structural and formal respects in Germany at least exhibit an almost general type. As a rule this consists of a sill, two jambs and the covering, that is usually composed of a tall angulas slab set

on edge. Fig. 1086 shows such a tabernacle from the church in Frankenberg.

The sill starts with a corbelled moulding a either cut off abruptly or returned at the ends, before the face of the wall with a wash above on which are wrought the starts of both the jamb members as well as of the angle buttresses set either square or diagonally. On the jambs occupying the height of the case is then wrought the member b as well as the buttress c.

In that tall and angular slab are continued the buttresses and the end in pinnacles, the jamb members combining in pointed arches, but the space for the case ends horizontally, so that in richer forms results a tympanum with foliage or figures. The arch is then crowned by a window gable which ends at the buttresses, so that the pinnacles start close above its ends. Above the window gable is usually a horizontal terminal cornice with battlements, either cut in the same slab or laid thereon, whose projection corresponds to the extreme end of the buttresses or is somewhat less, beneath which extend the crownings of the window gable and pinnacles, so that thereby is prescribed the same height also given by Roriczer. Thus the window gable is divided into three parts above the arch, that can be adorned in various ways. The working of the entire design in one stone thus permits the harmony of several projections, as with the crowning od the window gable with the pinnacle moulding, further a fertain moderation in the projection of the window gable, whose profile either directly joins the wash or a short horizontal part of the upper wall surface, and mainly leads to a form chiefly in the character of that given by Roriczer in Fig. 1067.

Different forms.

The exceptional character of the loading is thus also given always to the pinnacle in later works, in that this first rests above the junction with the window gable, an arrangement found in Fig. 1087, and also much later is expressed in even the smallest dimensions, so that as in Fig. 1126 the body of the pinnacle is still divided by a moulding on which rests the window gable. But it is lost in the mass when the junction of the window gable is placed higher, as by Roriczer on the base of the pinnacle, and almost entirely disappears when the pinnacle stands on the ground line of the arch, so that the window gable

penetrates its body. Thereby is connected also the replacing of the buttress by a little column or by a corbel, as may occur on a blind arcade crowned by a window gable. Yet with the last arrangement is again compatible the division of the body of the pinnacle by a moulding or the placing of the pinnacle on the intersecting window gable, as well as especially in smaller dimensions the pinnacles are omitted and the window gables rest on a corbelling.

From these different forms now come very varied proportions of window gables and pinnacles greatly differing from Roriczer's, as evidend by a comparison of the latter with the forms just described and also with those on p. 460 executed according to Lacher's principles. But the most striking contrast to Fig. 1067 is presented by the window gables from the tower buttresses of Cologne cathedral represented in Fig. 1087 from "Facsimiles of the original Sketches", as then generally an elegance of form is peculiar to all parts of the latter, which represents them al unequalled models, when already the earlier works and especially the French usually exhibit greater freedom of development. As an example of the latter kind, we give in Fig. 1088 a window gable from the tower buttresses of the cathedral at Rheims.

Recessed window gables.

Also the outline of the window gable suffers essential modifications in the later periods of Gothic art. Thus is first mentioned the crowning of that mentioned on p. 352, the mouldings concentric with the arch with stem and flower by means of a bending of the beginning of the junction of the stem to the form of the recurved window gable, which represents Roriczer's construction in its full development (Fig. 1067), and that can assume the most varied proportions of height, first in reference to Fig. 1067 according to the height of the point x at the apex of the arch, and further according to the form of the arch itself. By a lower form of the latter, i.e., that of the semicircle, then either with an unchanged height of the whole would result a predominance of the reverse curve over the arch (Fig. 1089), or a lesser height of the whole. But the latter would be still farther reduced by the assumption of a segmental arch or by the construction of the recurved arch by four points connected together as in Fig. 1090, such as produces that form of

covering the window frequently occurring in France in the Late Gothic.

This flexibility of proportions is however peculiar to the earlier forms of window gable in no less degree, for aside from the smaller size of the gable common to the older French w works, there also result motives from Fig. 1091, that make possible the retaining of any height. This Fig. shows a window gable over a segmental arch.

That predominance of the recurved arch over the arch itself is evident in Fig. 1089, and finally leads to the omission of the latter (Fig. 1092), and the pressure for ever novel changes in form to the compound shapes represented in Figs. 1092 a, b.

Intersecting window gables.

However even this motley diversity did not satisfy the masters of the later period. Men permitted the window gables to intersect, and finally even abandoned the vertical plane, when above an arched base line or the two sides of a triangle t they bent it outward, allowed the recurved window gable to be divided, and each half to continue farther in a recurve t the beginning of line of the recurved arch, and they finally even likewise carried the pinnacles also in these capricious ways, at last even passed from these still architecturally treatid to the freer forms of branches of foliage. We lack space here to go farther into this far reaching principle of Gothic construction, with the means of forms executed in a surprisingly artificial manner. These are generally termed affectations. Now one needs not to be warned from an imitation of these affectations, they are at the present time mostly opposed by the need of manual perfection, such as developed from the preceding centuries of Gothic practice, predominating for the time but not easily obtained. And thus also the perfection of technics all ensure to these degenerates of Gothic art a place in the history of art, that is still placed far above most modern art figures, designed in the present style and executed in cement or in similar substitutes.

6. Crownings and Crockets of Pinnacles and Window Gables.

Knobs and crossflowers.

[illegible]

Terminal knobs.

The simplest crowning form is shaped about like Fig. 1093, the stem with the knob first varies by a complex form of plan, for example by a concave shape of the polygonal sides or by the transition to the corresponding star shape of foil plans. These conditions of plan also make themselves felt in the elevation by the varied projections from the polygonal stems and the accurately resulting profiles. Thus Figs. 1094 to 1094 b exhibit a knob like a torus with hollowed sides, in whose section in Fig. 1094 b is visible the profile on a b and c d. A similar form likewise already peculiar to the Early Gothic period results from the mass of the knob, which is made diagonally, radially, or perpendicular to the sides of the polygon and indeed either as in Fig. 1099 a , may be through the angles or the middle of the sides, through both or between both. Figs. 1097 to 1099 show different stem mouldings formed in this way, which could also be used as crowning forms. Every cut is either left plain or filled by pearl beads, or there is found in it a slightly projecting member varying from that of the knob. There then the external surfaces of the projecting parts are usually divided by flutes in concave or convex shape, as Fig. 1099 a shows in plan, so that a similarity to certain kinds of gourds results.

The original profile of the knob, that shows a round or a lenticular member, is usually separated from the stem by a subordinate intermediate moulding or it ends above in a point (Fig. 1095 a), thereby obtaining a more bud-like and more or less compound form, (Fig. 1095 b, c), whereby however certain parts of the surface may be ornamented by flutes or any surface ornament like scales. On later works the bud form passes into the bulbous and pointed shape, or is cut off at top (Fig. 1095 d), or is replaced by a drip with flat or concave wash (Fig. 1095 e). The bud for richer development will be clearly expressed by t the enclosing and either cosed or opened leaves (Fig. 1102).

Crossflowers.

Richer and more projecting forms then result by the arrangement of several, first of 4 arms extending from the stem, that again terminate in simple or compound forms of knobs. Such shapes which are commonly comprised under the name of crossflowers, are allied to those earlier forms of capitals contained in Figs.

456 to 480, as then the term "capital" nowise includes the conception of support.

Thus the astragal of the stem moulding, those volutes supporting the edge of the bell swing freely outward, and the bell itself becomes the stem and the abacus the terminal knob. In this sense the before mentioned form of capital would easily be transformed into a crowning, and would first require a more slender ornamental form. In Fig. 1100 we attempt such a development, about from the form of capital represented in Fig. 480. There the extreme square a b seen in the plan of Fig. 1100 a determines the projections of the four arms, the square c d e those of the lower row of leaves, the octagon formed of it, those of the stem moulding, and the square h f g in the same sense the lower ground form of the stem. Likewise are developed the heights in elevation from the inserted squares harmonizing with the square a b of the plan, whereby the distance a i corresponds to the distance lettered the same on the plan, and the line ik thus given limits the thickness of the terminal knob and that of the buds.

As in Fig. 1100 the volutes forming the upper circle project beyond the leaves of the lower row, then is the converse proportion usual, whereby the projection of the lower row exceeds that of the upper, or that more important development in height, the upper exceeds about so that the successive squares of the quadrature give the sizes on the plan for the different rows in the given sequence. According to this system is constructed the crowning flower represented in Fig. 1096, and therein is given the development from the plan by the similar lettering. There the heights of the separate rows, thus 11, 22, 33, are determined by the sides of the corresponding squares of t the plan. A substantial modification is suffered in the character of the whole by the different proportions of the heights, which could vary on both sides from those here given, so that as in Fig. 1097 even the heights could be determined by the diagonals of the squares concerned or conversely, or as in Fig. 1097 a by the half diagonals. Likewise the proportionality of the heights of the plan dimensions nowise forms the general rule, but on the contrary the heights are usually ejual to each other.

In Fig. 1096 the plan division of the stem moulding is deter-

determined by the octagon formed on the outside square. The m resulting bold form is first of all peculiar to French works, on which a richer form of this moulding predominates, even to the degree that it dominates the row of leaves (Fig. 1101)and the whole becomes similar to the form of the bud.

The vertical direction attains to a more decided expression not only by an increased height of the separate parts, but also by an increase of their number (Fig. 1097), whereby the form approaches that of a stem with beginnings of leaves.

If this arrangement is already predominant, whereby the square of the lower row is set diagonally and the succeeding squares are diagonal to each other, then there is no rule in this, and likewise retaining the diagonal position to each other, the parallel position of the lower square is the parallel position of the squares to each other.

Further modifications of the form of plan result by the arrangement of 8 arms as in Fig. 1098, or by the more rarely occurring 6 on the hexagonal, or of three on the triangular stem. Still as a rule a hexagonal plan of the buttress or of the stem is connected with the square crowning, so that two arms project from the surfaces and two from the angles of the stem.

Formation of the arms.

In the earlier time the branches of the crossflower mostly have the shape of extending volutes or of boldly bending stems, which at their ends bear a bunch of leaves corled downward. (Left half of Fig. 1096). Later predominate those also occasionally found in very early times, forms of leaves ascending upward, that usually grow directly from the main stem (right half of Fig. 1096).

The simple line of projection seen in the right half of Fig. 1096 suffers the next modification by an increased bending of the ends of the leaves (Fig. 1099), which again as in Fig. 1112 leads the ends into a form like a ball, whereby may occur a deflection of the line connected may occur, so that the entire effect is again almost allied to that of the volutes. The transformation of the latter is still more expressed in Fig. 1104, in which the leaves have greater importance and decidedly swing upward instead of downward, while the arms on which they rest form an angle wfth the stem. These leaves are derived from the form of bud shown in Fig. 1102; from it by the opening of the

leaves to that of Fig. 1103, and thus farther by the combination of the different motives so far represented to the forms illustrated in Figs. 1106 and 1105, the first of which with an ever ascinding main line yet already shows some complex bends, and so permits the transition to the later forms.

Later forms.

For the later time therefore besides a more horizontal line of projection, there is an increased number of forms of bends with short breaks as a characteristic, about as Fig. 1105 shows, but soon the line of projection becomes a strongly recurved and again a sinkgin one, the bends are stronger and more swelled, and the separate parts of the leaves are animated by those spherical swellings (Fig. 1067b), that we have already mentioned on the leaves of capitals. On other leaves of the same period occur those exaggerations in a less striking way, and there result very bold and beautiful forms. Such an example from the upper terrace of the tower of Strasburg minster is shown by Fig. 1115 b. These swelled forms then follow certain predominant geometric ones, of which we give an example in Fig. 1108 from the upper balustrade of the tower at Freiberg, whose execution strongly contrasts with that of the greatest part of the foliage found there, and it is no longer to be attributed to the date of the erection of the spire. Besides the before mentioned diversities in the proportions of the stylistic keeping are to be seen certain marks more related to the main forms of the separate arms.

1. The form of plan of the entire series varies between the cross, that is expressed in the forms represented in Figs. 1096 and 1099, and the circle that rather dominates Fig. 1107. Between then then lie the forms of the quatrefoil and that of the square, which are more peculiar to the later feriod.(Flower contained in Fig. 1077).

2. The line of the upper termination is either ascending or horizontal, so that retaining the same form of plan and line of projection, there results the difference in the forms of bosses for the different parts as shown in the two halves of Fig. 1110.

3. The profile is either wrought in a direction parallel to the upper ending over the entire part, or is changed in the different parts of the leaves. According to the first mode of

treatment (Fig. 1109) the effect becomes more quiet and recognizable at greater distances, and this is found both in the f flowers of the earlier period as in those more folded ones of the later time (Fig. 1105). But it is only to be understood, t that the principal lines of certion parts of the leaves lie in the surfaces of the simple form of boss, and further modeling cuts it. The second mode of treatment expresses itself most c clearly in these projecting bends of Late Gothic foliage, and is already found employed in Early Gothic on certain parts of the leaves.

4. The direction in which the separate leaves or parts of leaves grow is either one away from the stem, or one recurved from the point of greatest projection. Figs. 1105 and 1104 exhibit these different motives. The first has the leaves attached to the underside of the volute supports already on the form of capital represented in Fig. 463, the second is to be referred to the different forms of the ending of the support.

The richness of these crowning forms can even be increased by combination with animal forms or figures, which crouch or stand on the stem and thus form its endings. Particularly beautiful examples of this kind are found on the buttresses of the side aisles of Strasburg minster. Fig. 1093 shows an example from the portal of the north transept of the church in Gelnhausen. Likewise such forms can replace the crowning as on the pinnacles of the choir of S. Ouen. (Fig. 1083).

Further as already mentioned for gables, the crowning may assume the form of a pinnacle or pyramid, as on the portal of the north transept of the cathedral of Chalons.

Conversely the pyramids may also be replaced by the ordinary forms of crowning, like the roof balustrade of the clearstory of the cathedral of Paris. The balustrades on the towers of the same work then exhibit a substitution of the pinnacles by animal figures, which stand inside the balustrade on its floor, and leaning over the parapet look out over it.

Crockets or angle flowers.

Crockets on the back of the coping.

Like the separate arms of the crowning from the stem, so start the crockets from the back of the window gable, and they can therefore pass for a continuation of the former, harmonizing with them in shape and size. This agreement can be complete

by adoption of motives of volute forms or of leaf forms derived therefrom, and may lead to the omission of the stem, and hence results the form shown in Fig. 1084 f. The continuity of the crockets with the arms of the crowning makes itself felt even with different size and shape, when the middle line of the crowning extends in that of the crockets, an arrangement which is contained in the window gable represented in Fig. 1085, but it also requires the profiling upward of the coping shown there, i.e., a considerable projection of it, and requires the termination with an edge or a rib connecting the crockets, as shown by Figs. 1111 and 1111a. In this case the crockets stand in a vertical plane, so that the cross section on a b recalls the form shown in Fig. 1111 a, and there can be employed all arms of the crowning shown in Figs. 1112 and 1114 as crockets.

Crockets on the wash.

In all these more ornamental forms op window gable mentioned on p. 474, which lie near the wall surface, where further the channel lying behind them is omitted, so that the wash is a short horizontal line on the wall surface (Fig. 1113 a), the vertical position of the crocket leads to a growth of it with the wall. Thereby the ending of the leaf always rising from the upper edge of the profile of the window gable receives a bend forward, so that the surface of the wash is covered by it. This arrangement is found on the crocket in Figs. 1113 and 1113 a, from the wall tabernacle of the church in Friedberg. This further leads to extend the starting point of the leaf from the upper edge down on the surface of the wash, and to change the line of its movement from the vertical plane to one more inclined and perpendicular to the line of the wash. Hence results the peculiarity that the leaf now exhibits its surface development, instead of this profile in the front view as in Fig. 1111. Figs. 1115 and 1115 a show such crockets from the upper story of the square of the south tower of Strasburg minster.

By this varied position is further given the possibility of a freer treatment as proved by Figs. 1116 and 1116 a from the south portal of the Franciscan church in Fritzlar.

But there remains predominant until the last period of Gothic art the retaining of the motive resulting from one arm of the crowning in combination with a nearly perpendicular position

of the line of the wash, whereby the points of the leaves of the averted side remain visible over the line of movement of the whole, even when the edge of the window gable forms the starting line. Fig. 1117 shows such a crocket, that is seen sidewise in Fig. 1117 a and in Figs. 1117 b, c, is projected at 45°. It is at the same time peculiar to the later period, from the mode of drawing peculiar to it is visible the inclination to perspective representation, that is also expressed h here. Care was taken since something of the effect of the leaf might be lost.

Differing forms.

The taste for ascending curves, which characterized the later period, also then led to a modification of the line of movement, whereby the leaf or crocket, instead of rising in the direction of the window gable, rests thereon by a later bend in a horizontal direction, and this from an attached part becomes an addition laid on it. This conception is most clearly expressed in those forms, that show the beginning of the leaf uncoiling from a short branch cut off at both sides and lying on the wash. (Figs. 1118, 1118 a). Indeed scarcely is needed a reference to the advantage of the earlier form developing itself from the members of the coping, and the effect of the angle flower strengthening it for the later, thereby completing and in a sense resisting.

The crockets sometimes project horizontally without regard to the inclination of the gable, and their effect is trailing in a way, but on account of their strength they were preferred to the before mentioned swollen buds. Fig. 1119 shows such an example from the gables of S. Vaudru in Mons.

Simplifications.

In smaller dimensions, as they first appeared on the pyramids of pinnacles, certain simplifications are necessary for the crockets, already expressed in the word "crockets"(Laubbossen) in Roriczer, that we have also retained for the richer forms on window gables. From "boss" it denotes the principal form, the body further detailed, which the stonecutter must work out of the rough mass before he proceeds to the latter.

Since now the closer detailing is arranged according to the actual size by its distance from the eye, in smaller size it is omotted and the bosses become the complete form, but this

is to be simplified in continued reduction. Thus Fig. 1120 represents the bosses on a leaf contained in Fig. 1106, or in Fig. 1120 a again the bosses in Fig. 1120 and both forms could appear as leaf bosses (crockets on pinnacles).

The same condition results for smaller dimensions of window gables, so that Fig. 1121 represents the bosses in Fig. 1117, which then by simple modeling receive the form given in Fig. 1121 a. Yet there is always found a tendency toward nature, to the motives of certain simpler forms of leaves instead, and F Fig. 1021 b shows a direct imitation of nature. But also here by retaining the older motive of the volute-like form as in Figs. 1085, 1088 is most easily found the measure of simplification and a stronger contour of the whole is obtained.

7. Canopies and Pedestals.

Canopies form protecting roofs over single figures, a continuous series of figures or reliefs, and therefore in smaller dimensions replace the before mentioned shrines, developing in their simplest forms from those represented in Figs. 1058 to 1060, so that the slab or tunnel vault is separated by corbels projecting from the wall instead of detached columns. An example of the last kind is found on the exterior of the cloister of the cathedral of Laon.

But in the degree that the dimensions permit the execution of the canopy in a simple stone, the corbel becomes superfluous, and it then assumes a typical form af a vault on a polygonal or round plan with suspendeng arch springings and vertical external walls, which then in the simplest way is covered by a horizontal simple or battlemented cornice with a graceful crowning in richer developments.

Treatment of additions.

The older and richer examples exhibit a certain relationship with the forms of those chandeliers, of which we find the most developed types in Hildesheim and Aix-la-Chapelle, and which consist of a hbrizontal circular hoop or one in quatrefoil shape in metal, which is beset by turrets, castles or other buildings at regular distauces. In Hildesheim this combination of buildings with entire decision passes into the representation of the heavenly Jerusalem. If it was next to conceive the chandelier as disseminating the heavenly light, and in this sense to adorn the city of God, then the canopy should replace the

nimbus or halo, whose representation was little suited to the means of sculpture. This relation very frequently leads to a certain harmony of treatment, that on certain particularly prominent examples goes to the intended representation of the same objects. On the contrary there appear on most an architectural treatment of the given motive effected with the greatest freedom and essentially differing from the form of all other parts. For it is here even the capricious element, which here where it only concerns the artistic form of a stone soaring o over the figure, and not the connection of it with others, thus being a real structure, makes effective in an overpowering degree, in like manner as this is also the case in the pointed architecture of the glass window.

Thus these additions above the horizontal or the termination of this vault by little gables mage by the most varied combinations of simpler or richer buildiggs and towers of one or more stories, that rise in one or several stories over each other. The plan of the single series is related to that of the vault about so, that over the middle of each polygonal side stands the building proper, over its angles rise the flanking turrets, and the second series is placed alternately on the plan of the lower one, and also well forms a simplification of it, but from the whole rises a massive tower in a sense as the citadel of the city, which serves as the pedestal of several figures placed above the upper one.

Suspended springings of the arches.

Thereby is expressed the ornamental character of the whole further in the reduction of the size of the suspended arch s springings, that are based only on the possibility of execution in stone and not according to the proportions required by an actual vault. These arch springings as a rule are then either cut off horizontally on the base line of the vault, or they are inclosed by a leaf form developed from the members. Figs. 1122 to 1124 exhibit such examples from the so-called angel's column in the south transept of the Strasburg minster, the north portal of the cathedral at Rheims, and the buttresses of the south side of the Freiburg minster. On such points that permit or require special accenting, are sometimes interwoven figure elements in the form of the canopy. An example from the west portal of the church at Volksmarsen is shown by Fig. 1125,

where the cross ribs of the canopy of the portal arch are held by two angles projecting from the mouldings of the arch, whose abutting wings form the side arches. A simpler arrangement of this kind is found in Viollet-le-Duc, Vol. IV, p. 437, where the angel rising from the shaft of the colunm with expanded w wings forms the canopy.

This freer mode of treatment is predominant untel the close of the 13 th century, es the west portal of Strasburg minster exhibits very charming forms of this kind, in which the most intimately developed system of pinnacles and window gables always makes itself more distinctly felt. But soon also reappears that freedom resulting from the nature of the matter, which makes itself known in the gracefulness of the ending arches. Their size simulates a structural need, and they are formed with greater ornament, so that the idea cannot suffer any manual awkwardness arising from its increased size; they rest on projecting and more or less compound corbels (Fig. 1126), or the pinnacles or buttresses flanking the angles extend down to the corbels, and the arches and gable mouldings intersect them. Accordingly results a polygonal form spanned by a cross vault as the type of canopy, so that very simply the columns are omitted and their capitals are changed into projecting corbels. In this sense can all arrangements given for the shrine and t the complex shapes of pinnacles also find employment here.

As already stated, canopies must protect the figures standing underneath on corbels, columns or piers, so that from them results a certain relation of their plans to those of the pedestal, which usually occurs so that the inner clear width of the canopy equals the external one of the pedestal. A harmony of the ground forms is usually found, yet without being rejuired by the nature of the matter.

The entire form is attached to a plane surface, an angle or a column.

Form before a plane surface.

In the fist case the canopy usually occurs in combination with a niche increasing its plan to the entire polygon (left half of Fig. 1127), so that half the springing of the arch rests on the little columns a and a', or the niche is formed as a circular segment, so that rib 2 is omitted, or finally there remains standing only the little columns a, a, and they

are connected by a side arch. In the simplest case these columns are also omitted and the arch springings a rest directly on the wall. But it is then preferable to indicate the background of the figure for the breadth of the canopy by a pattern or at least by a colored coating.

The little columns a either stand on the outer edge of the pedestal, or if the plan of the latter does not suffice, or they are corbelled out above the pedestal.

Figure before an angle.

For a canopy before an angle, as a rule this is chamfered in the height between canopy and corbel.

Figure before a column.

Before a column or a round project the canopy and pedestal according to the earlier arrangement, so that certain headers form the column or round, while the figure is either wrought from a cylindrical block behind and standing on end, or both consist of two placed beside each other. Here then also the pedestal is sometimes carried down to the ground, a column being placed on it, and with the same it is wrought from one block.

As a rule on later works the part of the column or round for the height of the figure is omitted, so that either the lower part of the column terminates with a separate capital bearing the figure, or a projecting corbel is arranged for the latter, beneath whose upper edge the former stops (Fig. 1126 at a), while the part continuing above the canopy is either corbelled out above that (Fig. 1126 at b), or rests on it. It scarcely requires mention, how very much the earlier arrangement excels the later, the static function of the round by the interruption increasing in consequence.

As already stated above, the pedestals of the figures as corbels, columns or piers, that by their construction fulfil other functions, do not differ in general; certain peculiar forms c connected with forms of portals can only be investigated together with the latter.

We have already shown on p. 242 how for the understanding of the subject represented is usually aided by a legend placed on the corbel. The same explanation is also frequently found in a finer way by secondary figure representations concerned with the meaning of the whole either directly or by contrast. These are then interwoven in the ornamentation of the capital

or corbel, or on the portals of many French cathedrals, it takes the form of a low canopy, under whose vault the smaller f figures crouch and almost fill its space, or finally the representations in relief concerned are found on a low pedestal s set on the proper support of the figure.

Likewise the column in the position in question usually assumes a freer form, sharply accenting the more structural character of the round. In Fig. 1128 we give an example of this kind from the vestibule of the north transept op the cathedral at Chartres.

VIII. WINDOWS AND TRACERY.

1. The Window in General.

Development of the window.

Protected position of openings for light.

Before the general introduction of glazing the closing of openings for light was a kuestion, which decisively influenced not only the treatment of these openings but the entire form of the building. In order to create larger openings for the living and occupied rooms, that were protected from the inclemency of the weather and sheltered from the noise and dust of the outer world, men sam themselves compelled to place projecting roofs or porticos before the rooms, and to have the latter open on internal closed courts as much as possible. This opening of the rooms toward the interior finds its corresponding expression in the plan of the antique house, and was transferred to the cloister of the monastery in later centuries, but for the latter certainly were added further reasons for the separation from the external world.

Openings without closure.

But now such a protected position could not be assigned to all windows, and they must often be placed in the outer walls, very particularly in great and spacious monumental buildings. If this concerned subordinate openings for light and air, that perhaps led into rooms of less importance, then they were left entirely without closure, just like many windows in towers and gables at this day, or at most in special cases grilles or wo wooden shutters for occasional closure were placed before them. To prevent the entrance of rain as much as possible, such free openings are made relatively small, since then the greater thickness of the wall aids to protect. Instead of a great window, several small ones are placed beside each other, that in some cases are comprised by a common arch, their appearance having the expression of a single great window.

Transition to glazing.

The windows on great monumental buildings, to be left entirely open especially in churches, were not always required even in southern countries, and a temporary closing by shutters was difficult to execute for artistic and practical reasons, especially in high windows, and men must therefore devise a closure for admitting light and keeping out weather as far as possible,

that were found in the Byzantine period in perforated marble slabs often richly carved. (Whether and how far these already exhibited partly inserted pieces of glass must remain an open question). Since these slabs stopped much light, the window openings were not made too small, and only later when first in the 10 th and 11 th centuries they employed more and more the then very costly glazing with colored glass set in leads, these were reduced to the very least dimensions, so that even early large windows sometimes appear to have been reduced later.

In the sama degree that the manufacture of the glass was perfected and cheapened, could all window surfaces be increased, the more because at the same time the development of the system of support of the wall was more substituted in the place of the simple enclosure of the room, when men could freely open it w without injuring its durability. Thus in the beginning Gothic men were in position to develop at the greatest scale the glass area according to any practical or astistic requirements, which was done more willingly, because the ever more splendidly developed glass painting in the meantime supplied the charmingly effective ornamental decoration.

Glazing the window.

Size of the pieces of glass.

The size of the easily obtained pieces of plane glass was limited, they did not exceed in any direction much more than the length of the human hand. These pieces must be so joined that the joint allowed entrance of no air or water in an annoying manner, and as a suitable material was employed the very flexible lead, which until the beginning of our century maintained its unlimited importance for the making of window bars. Lead bars as shown in Figs. 1129 to 1129 b in nearly natural sixe in cross section have a middle web and two flanges, whose widths are between 3 and 7 mm. The bars are cast in moulds, and the drawn lead first came into use since the Renaissance, whose use is recognized by the impressions of toothed wheels on the web. Accroding to the cartoon fasterned on the working table are cut the pieces of glass, and then at a corner they are inserted in the grooves of the leads laid between them, which are easily bent and as far as possible are made in one piece; Where they abut against each other, the ends are cut off square or oblique with the knife anf soldered on both sides. In this

manner a panel of square, rectangular or any other shape is f formed to correspond to the portion of the tracery, and they it is enclosed by a common lead bar, or by one with a grrove on but one side (edge bar); although this lead inclosure of the panel is not always found on mediaeval works, it is well to make it.

Dimensions of panel. Saddle bars.

The breadth of the panels, on account of the necessary stiffness, cannot well exceed 60 to 100 cm, but usually amounts to only 50 to 75 cm, and for such panels one is also already compelled to place thin round (rarely angular) iron rods of 6 to 10 cm diameter, the so-called saddle bars (wind), that are fastened to the lead bars by lead strips wound around them and soldered to the lead bars. The iron bars are best placed in the shortest direction of the panel, but not to disturb free view, they may be oblique to the bars or be curved. The ends of the iron rods are usually hammered flat, that they may be fastened in the edge bar. For windows very strongly exposed to the wind, saddle bars more than 60 cm length by 20 to 30 cm apart must not be under 1 cm diameter, if they must prevent a bending or even a crushing of the panel, and particularly with valuable glass paintings must be used strong saddle bars near together, and the width of the panel should not be allowed much to exceed 60 cm. For windows little or not at all exposed to wind, these considerations do not apply, and thew need only s some thin iron bars, which preserve the plane surface of the panel.

Technics of glass painting.

On the technics of glass painting it may be briefly stated, that in the Romanesque and Early Gothic time was only known a single dark brown painting color, the black lead with which t the outlines, ribs and leaves and darker grounds of the ornaments were applied, but otherwise each color tone in even small areas must be inserted as a separate piece of glass. Great areas of the same color, that exceeded the dimensions of the glass, or their hooked form could not be cut out, were composed of several pieces by the aid of division (extra) leads. In the 14 th century appeared a new painting color, the artificial yellow, and further men began with red glass that was always flashed glass, sometimes ground off white; later was set glass

with other colors applied on one or both sides, and at the beginning of the middle ages men commenced to lay all colors after each other. These changes commencel at first by the use of too many dividing bars, and later by the changed tendency of taste; yet the more that the technics of painting was perfected on the one hand, on the other the more the architectural effect of the surface suffered damage.

Besides the manry colored windows there occurred those windows painted only with black lead in hatchings (grisailles), with the use of scattered pieces of colored glass or even without them. Finally in consequence of the strict rules of orders (Cistercians), instead of windows in strong colors were commonly employed those of white glass set in lead patterns, few of which still remain.

Highest in their monumental effect must incontestability be the windows composed of deep tones in mosaic effect of the earlier period, that in their ornamental and figure representations always present an united rich but quiet picture suited to the surface. (See Schäfer and Rosstäuscher, Ornamental glass painting).

Dimensions of glazed windows.

Only for windows of very small size, little round windows or those subdivided by tracery, is it possible to close the entire opening by a single glass panel composed in the manner d described above, but as a rule the window requires the placing of several panels beside each other. If the panels are joined in height alone (Fig. 1130), the window can have only a clear width of 70 to 90 or at most 100 cm, but on the contrary if there is a division also in width (Figs. 1131, 1132), then the breadth of the window may increase to about 150 cm, thereby u usually reaching the limit. If it be necessary to open a wider area, then must several such windows be employed beside each other, that are either separated from each other by solid pier of wall or at least by stone mullions.

In the time about 1200, when a pressure for creating wide openings strongly occurred, but the tracery first began its development, there existed windows of more than 1 1/2 or indeed more than 2 m (Rheims, etc.), which were subdivided into a network of square panels by the use of strong iron bars.

Junction of glazing with jambs and mullions.

it now concerns the fastening of the separate panels of glass in the window, where they abutted against the jamb or the middle mullion, it was either slid into a groove (Fig. 1133), whereby the panel necessarily was somewhat bent during the insertion, or the glass panel was laid against a rebate (Fig. 1134), that only required a width of 1 to 1 1/2 cm. On windows exposed to strong windu, the rebate faced outward, so that the window was set from the outside, and the putty was added on the exterior, and the wind pressed the window against the face of the rebate. Protected windows and those near the eye were also very frequently inserted from the inside. The rebate or the groove was caulked with lime and hair, recently mostly with putty or less well with cement.

Storm bars and cover bars.

The line of junction of two adjacent panels requires strengthening and ornamentation by a special arrangement. Here are placed strong iron bars 25 to 40 mm wide and 8 to 15 mm or more thick, that are called storm bars (Fig. 1135), whose ends are sunk 4 to 8 cm deep in the jamb or mullion, best being equally inserted in the masonry and firmly set in lead or otherwise so firmly fastened, that they cannot become loose. Less good is setting after erection, which is made possible by sinking a deeper hole and afterward drawing the bar out to enter the other end.

Storm bars must be set flush with the face of the rebate, so that the glass panel can rest all around. To hold and fix the glazing, the storm bar on its middle line at about 20 to 30 cm apart has projecting clamps, k in Fig. 1135 through which are driven little wedges or curved keys s after placing the panel. Instead of placing the key directly against the panel, it is better to place a cover bar (d in Fig. 1135). It has the same width as the storm bar with a thickness of only 3 to 5 mm and fits over the clamps with mortises, and by driving the keys the glazing is clamped between storm bar and cover bar. Clamps and cover bar are naturally on the same side as the glass panel, thus generally being outside.

Already on wide windows (Figs. 1131, 1132) occur crossings of horizontal and vertical storm bars, and thus they appear yet more on round or tracery windows, where result divisions according to the mode in Figs. 1136 to 1136 b. On the so-called

foiled windows a storm bar generally extends around at the ends of the cusps (Fig. 1136 c). It is natural that the entire design of the window should be in harmony with the storm bars as much as possible, so that the latter may assume a rich arrangement, an example of which is offered by Fig. 1137 from the west front of the cathedral of Rheims.

At the crossings of the storm bars is a bend to avoid weakening the junction, as one must extend over the other (Fig. 1138), as the old works show.

One of the cover bars extends through at the intersections, while the other abuts at its ends, but the ends of these bars require no fastening at the jambs. In recent windows sometimes a narrow cover bar is carried around the entire perimeter of the window in order to press the glass panel against the stone rebate, but this is useless as a rule, for good puttying mostly suffices, and the wind bars ending at the jamb are fixed in little holes in the jamb or in the groove.

Dimensions of cross section of storm bars.

So that the storm bars may well resist the wind anf not bend too much, they must not be made too thin and their ends must be firmly fastened. A bar with movable ends breaks 1 1/2 times easier and bends 5 times as much as a fixed bar of the same cross section.

Assuming a wind pressure of 120 kil per sq. m and a permissible stress in the iron of 1000 kil per sq. cm, there are collected in the following Table the required dimensions of storm bars for different lengths and distances apart.

Sizes of storm bars.

Proper size and deflection d under wind of 120 kil per sq. m.

Span	Dist.	W.	Th.	d	W.	Th.	d	W.	TH.	d
cm.	cm.	mm	mm	mm	mm	mm	mm	mm	mm	mm
75	60	25	9	2.0	30	8	2.1	35	8	2.3
75	90	25	11	1.6	30	10	1.7	35	9	1.9
100	60	25	12	2.6	30	11	2.8	35	10	3.1
100	90	30	14	2.3	35	13	2.5	40	12	2.7
125	60	30	14	3.6	35	13	3.9	40	12	4.1
125	90	30	17	2.9	35	16	3.1	40	15	3.4
150	60	30	17	4.4	35	15	4.6	40	14	5.0
150	90	30	20	3.5	35	19	3.8	40	18	4.0

Note. The thickness is given in entire mm for fractions over 1/3.

The tabular values again show a striking agreement with the experience of the ancients, are established for fixed ends, b but since these cannot be assumed with certainty, the thicknesses of the bars are to be increased about 1/5, so that the stress in the material remains the same; such a stronger bar with movable ends always still bends nearly three times as much as given for the fixed thinner bar in the Table.

Bars 125 to 150 cm long come in question only for windows w with vertical divisions (Figs. 1131, 1132), where so little is to be counted for the stiffening effect of the long vertical bars, that the transverse bars alone must be able to meet the wind pressure. For such great lengths in less severely historical buildings now, by utilizing the advances in our technics may also be employed T sections 3 1/2 to 5 cm wide, whose webs a b can be directly utilized for passing through the keys. (Fig. 1139). By bending the outer edge from a to a′ is formed a drip protecting the lower joint, or for the same purpose may be bent over the iron bar a strip of lead, copper or zinc, which at the same time protects from rust and could also form an internal channel for condensed water. But in general the construction of the middle ages is so well preserved, that it scarcely needs protection.

Window jambs and sills:

Form of jamb.

For openings without glazing, the wall has a simple rectangular jamb or one with reveals (Figr. 1140 to 1141). Some closing shutters lie against the surface of the wall or of a rebate, (Fig. 1110 a), they fit into a small rebate (Fig. 1140). On the contrary glazed windows have from the very earliest time onward splayed jambs, by which with the small width of window in relatively thick walls the light must be admitted. The splay is shown in its plainest form (Figs. 1143, 1143 a), or it occurs in combination with mouldings more or less rich (Figs. 1143, 1143 c), or it is entirely lost in mouldings (Fig. 1145), like the jambs frequently occurring in Middle Gothic (Figs. 1144, 1144 a) or in Late Gothic (Figs. 1145, 1145 a). As a typical example of a stepped window jamb may be taken Fig. 1142; Fig. 1142 a shows the same transferred to brickwork from the westbuilding of the cathedral at Riga (middle of 13 th century). Further examples of jambs are contained in Figs. 1146, 1148 to 1148 c.

The relations of the window to the covering side arch have already been described above (p. 350), and likewise it has been already stated, that the window jambs in some cases may coincide with the sides of the buttresses, or even be sunk in them.

Wall mullions.

For windows with middle mullions the regular development of the tracery (see below) requires carrying down the members of the mullion on the side jambs, so that here result half mullions, the so-called wall mullions.

The wall mullions are connected with the jambs, or where these are absent, with the buttresses, so that their separate piers remain in the height of the courses. More rarely they consist of tall blocks set on end, which then in the manner shown later for tracery are connected with the jamb. More frequently occur both conditions combined in the same window, as shown on p. 172 in regard to the rounds.

Window sill.

On the lowest block of these remains the start for the window sill (a in Fig. 1146), in whose height are generally taken the bases of the little columns b accompanying or forming the mullions. This construction is opposed to that commonly used, whereby the window sill is made of one piece for the entire width of the window and passes beneath the jambs, and is preferred since it avoids the breaking of the sill, that must occur if the sill extending under the jamb is chinked underneath the middle and a strong settlement of the jamb occurs. A distance of the end joint from the jamb members and thus the hook-shaped form of the stone are necessary to prevent water from flowing down the jamb and directly entering the joint. According to the thickness of the wall, the window sill consists of two or more ashlars laid on each other, or of but one for less thickness. The existence of bed joints then leads to making the angle of inclination of the sill greater that 45°, so that the edge c of the cut stone may not be too acute. Sometimes according to Fig. 1147 the upper stone of the sill is made of a stone with the width of the mullion, yet so that a lower wash does not continue the upper one, but a little vertical fillet a is left, below which continues the wash, while it may pe continued in a horizontal surface inside. It should be noted, that a steeper inclination of the wash is ever favorable, if possible for more

than 45°, and by the contrast to the other vertical and horizontal surfaces produces an animated effect, the arrangement of the bases of the little columns connected with the mullions is made easier, and opposed to flatter inclinations afford the advantage of being visible to greater height. The bases of the columns may either all lie at the same height, or as in Fig. 1146, these may be determined by the bed joints at different heights, They seldom lie above the window sill.

Window mullions.

The isolated dividing mullions are made of tall blocks standing on end, and on the older works maintain their vertical position by their weight alone without continuous iron bars. On the contrary on many later works the mullions are made so very slender, that this aid is required. No explanation is needed, how very much preferable is the older way and how injurious may become that iron bar. But since an increase in proportion to the increasing height has its limits, among others the appearance must lead to a greater width of panel than is favorable to the plan of the glazing, it must be advisable to restrict the height of the mullions, either by a reduction of the height of the entire window, or by a lowering of the tracery, so it already commences below the base line of the window arch. By the latter procedure (as we shall soon see more clearly), the weight of the tracery and thus the loading of the mullions will therefore sometimes increase the stability. On many works of the 14 th and 15 th centuries is found a stiffening of the mullions by cusped pointed arches, that are also sometimes connected with richer arrangements of tracery, trefoils, quatrefoils or squares with cusps, thus creating a cross connection of the mullions at half their height, commonly the arches being omitted, the connections merely consisting of squares arranged side by side or even of horizontal mullions.

On the lower block of the mullions remain the starts for the sill in the same manner as for the wall mullions (Fig. 1146).

Insertion of the tracery.

The whole of the tracery is then inserted in the window arch in the same way as the wood paneling in the frame, either in an angle (Fig. 1148) or a hollow (Fig. 1148 a). Besides there is frequently a recess (Fig. 1148 c) or a groove and tongue, (Fig. 1148 b), that is only short by the nature of the stone

and the purpose, 3 to 5 cm long but broad. By Viollet-le-Duc is also mentioned another construction by which the tracery stops abruptly under the window arch and by certain clamps projecting from the latter the supporters of the capittals are insured against all movement sidewise.

The tracery in some cases forms a centering arch for the window arch and must then be erected before turning the latter.

Dimensions and loading of the mullions.

Size and form of cross section.

To establish definite proportions of dimensions between the mullions and the thickness of the wall, as the later middle ages seem to have loved (p. 352), for example to make the depth of the mullion 1/3 or 4/10 of the thickness of the wall, must be termed a tradition of the early time and a procedure taking little account of static requirements. There was nothing in the way of increasing in dimensions the mullions of small windows to place them in harmony with the jamb mouldings or with larger neighboring windows, but in general there is nothing decisive but the size and especially the height of the window, so that small windows in thick walls can be satisfied by relatively slender mullions, while conversely for high windows in thin walls almost the entire thickness of wall must be used to be stable.

The ground plan of the mullion is made thin with reference to the admission of light and is splayed outside and inside in harmony with the jamb (Fig. 1149). On the contrary the depth of the mullion is considerable, since in this direction it must resist the wind pressure. Most ground plans of mullions can be referred to about the simplified ground plan of Fig. 1150, after equalizing projections and recessions. Such a ground plan of the average thickness b, outer and inner widths of $\frac{b}{2}$ and a depth of 2 b, has an area of $1.5_4 b^2$, and in the greater direction a moment of inertia of $\frac{5}{12} b$, or in the smaller direction one of $\frac{5}{64} b^4$. The inserted figure of the kern has a length of $\frac{10}{36} t$.

The mullion must be sufficiently strong, that it is not crushed under its load, that it does not bend sidewise, and finally that it is not bent by the wind.

Maximum load for resistance to chushing.

With not too slender mullions, the loading that can be assigned to them depends only on the resistance of the material to

$$r = \sqrt{\frac{\quad}{\quad}}\,.$$

crushing. On account of the readily occurring change to an excentric load, it is advisabletto keep the stress within moderate limits, and with an abundantly 10-fold safety, to allow only 5 kil per sq. cm for brickwork in lime mortar, 10 kil for good bricks in cement mortar or ordinary cut stone, and at most 20 kil for hard cut stone set with special care. Accordingly a cross section of the form of Fig. 1150, 15 cm thick and 30 cm deep has 338 sq. cm area and if executed in ordinary brickwork could receive 5 × 338 = 1690 kil, or in hard cut stone 20 × 338 = 6720 kil. In Table A on p. 496 under P are given the permissible total loads (load + weight) for a number of cross sections nf mullions.

Loading and height of mullion on account of buckling.

If the mullions exceed a certain height, the danger of buckling will be greater than that of crushing, in consequence of which this load is then to be kept within correspondingly smaller limits. Calculate by the given formula the permissible load N for the height of the mullion, (and conversely) by the general formula for buckling:-

$$N = n\frac{\pi^2 E J}{s l^2}.$$

Here N = load resting on it together with the weight of the upper half of the mullion in kil; n is a coefficient depending on the mode of fixing the ends, and here by correct construction lies between 1 and 4, but for safety is only made = 1; $\pi^2 = 3.14^2 = 10$ in round numbers; E = modulus of elasticity, that according to the certainly still defective investigations for bricks is given at 150,000, for soft cut stone at 250,000, for hard cut stone at 400,000:- J is the moment of inertia in the direction of bending; s is a coefficient of safety that may be taken at 10, and finally l = length in cm.

If no storm bars exist, the mullion would bend sidewise, and thus the least moment of inertia ($\frac{5}{64} l^4$ in our cross section) is to be considered. The Table gives under J_{min} these moments of inertia for different cross sections, and further in three columns under l_1 is the permissible height of the mullion for a full load P, with half that load, and for the effect only of its own weight. A mullion 15 cm thick and 30 cm deep could be made for a full load 4.8 to 6.0 m long, for a half load 6.8 to 8.4 m, and for its own load alone 12 to 16 m, to have the desrable 10-fold security against bulging sidewise.

If it be then assumed that the storm bars form a sufficient stay between the mullions, then bulging can only occur in the direction of the depth. The maximum moment of inertia is then found in the Table under J max, while the allowable lengths of the mullion are found in the 3 columns under l_2 The permissible length under full load is about 40 times the depth of t the mullion. If with model execution and perfect building materials one would be satisfied by smaller safety (5 or 2.5 instead of 10-fold), then the tabular values could be increased 50 to 100 per cent, so that with sufficient staying sidewise the mullion could be made 60 or 80 times as high as deep.

The possibility of such a slender mullion depends on the conditions of the elasticity and resistance of the stone, and also round or square piers of stone can be relatively much more slender than those of wood or iron. While for a round or square wooden post with a length equal to 10 to 13 times its diameter buckling occurs more easily than crushing, this is found for a stone pier to occur first at 25 to 40 times its diameter, a fact again correctly recognized by the ancients, when it must have been utilized, as among others is shown in the p piers in the castle at Marienberg, the Brief chapel at Lübeck, a side chapel of the cathedral of Riga, and the slender little columns before the rose window of Strasburg minster. For heavily loaded piers moreover one would do well not to make the s slenderness more than 1 to 20 or 1 to 25.

Allowable height against wind pressure.

If thereby greater latitude is left to the length of the mullion in regard to the danger of bulging, the closer will the limits be chosen if the window is exposed to a strong wind pressure, as shown in the last three columns of the Table, which are calculated by the formula given below. A brick mullion 15 cm thick and 30 cm deep accordingly with distances apart of 75 to 100 cm can only be 3.5 or 3.1 m long, with execution in cement mortar, or 5.3 to 4.3 m in cut stone, or for hard cut stone 7.1 to 6.1 m. These are no great lengths and still for windows placed high only a moderate wind pressure of 120 kil per sq. m is taken, while a strong edge compression up to 10 kil per sq. cm is taken for brick in lime mortar, 20 kil in cement mortar or for cut stone, and 40 kil are allowed for hard cut stone. To go much above the tabular values is not advisable accordingly,

the more that the stress increases in the square of the proportion to the length of the mullion, and the danger of irregular construction increases. If the values were exceeded 2 to 3 fold, then even with faultless conditions a destriction would be expected, and too slender mullions could only be made durable by sufficiently thick and continuous storm bars (p. 492), that firly fasten the mullions to the jambs. Aside from the danger of rusting, the dependence on continuous iron bars has the great defect, that mullions are braced and the vibrations loosen the joints before the flexible bars become effective.

Least load for preventing bending by the wind.

The wind exerts on a mullion an effect similar to the load on a straight arch, in consequence of which the upper and lower ends of the mullions receive end pressures comparable to the thrust of the arch, which the masonry resting on the mullion at top tends to compress. Therefore a sufficiently great weight of masonry can oppose the upper end of the mullion. Thus besides the upper limit of load on the mullion (P in the Table), there is also a lower limit, if the wind does not break the mullion. This fact is of sufficient importance to demand a closer consideration.

So that the mullion may not be broken by the wind, there must be formed in it a line of support with the rise x and the end forces D (Fig. 1151). Establishing the moment equation for one half the mullion there is obtained for D and x the relation:-

$$D\,x = \frac{w\,l^2}{8}\,.$$

In this l = height of the mullion in cm, w = wind pressure acting on 1 cm height of mullion and glass surface. At the upper end of the mullion must the end force D or more accurately its vertical component be just as great as the upper load on the mullion, end if this is fixed, then the rise x of the line of support is to be obtained by the equation above. The smaller is D, the greater is x, but the latter must not exceed a definite magnitude, if the mullion is to remain permanent. If x equals the depth t of the mullion, rupture will certainly occur, for the tensile resistance of the mortar cannot be especially relied on here. Usually x is not taken at more than about half the depth of the mullion, or it would be safer if not over the length of the kern ($\frac{10\,t}{36}$). When such an $x = \frac{t}{2}$ or $= \frac{10\,t}{36}$ is inserted in the equation, then is found the least permissible

value of the load D on the mullion. (See Table that is established on the assumption that $x = \frac{t}{2}$).

Example. Required the least load on the ordinary cut stone mullion 4 m high, 20 cm thick and 40 cm deep, so that it may afford sufficient security against wind pressure of 120 kil per sq. m, when the distance of mullions on centres is 90 cm. In the formula are inserted x = 20 cm, l = 400 cm, $w = \frac{120 \times .90}{100} = 1.08$.

$20\ D = \frac{1.08 \times 400^2}{8}$ 5 hence D = 1080 kil = least load. (For x = 40 cm, D = 540 kil, and rupture would already occur). If greater safety is desired, then x is made = the length of the kern = 11 cm, which gives as the least load 1960 kil or 2000 kil in round numbers. The maximum permissible load P on this mullion according to the Table = 6000 kil, which includes its own weight of about 500 kil, and thus the maximum extra load = 5500 kil. Therefore one must design so that the mullion has a maximum load of 5500 kil or a minimum load of 1080 or better 2000 kil, thus 1/2 to 1 cu. m of stone.

Similarly may be calculated for every case a maximum and a minimum limit of loading, which further coincide more nearly, the more that the length of the mullion approaches the upper limit. For the lengths of the mullions given in the last 3 columns of the Table, the maximum and minimum permissible loads c coincide entirely with the load P, if the condition be established, that the pressure remains within the kern, and the edge pressure shall not exceed 10, 20 or 40 kil. For relatively long mullions the load must be determined with especial care, if the material is not to be stressed unduly.

In Table B for six different cross sections of mullions are given the least loads for safety with a wind pressure of 120 kil per sq. m, indeed for average distances between mullions of 0.75, 1.00 and 1.50 m, with a height of mullions from 2 to 10 m. For comparison are given the maximum limits of the loads required by compression, that already are in Table A, but are again repeated in the last 3 columns. On this Table it may be stated, that the minimum loads given under D suffice for well executed windows not too much exposed to storms, but with inferior execution and exposed location is required an increase of 9/4 or double, while on the other hand for especially protected windows the loads on the mullions may be als reduced.

For Tables A and B see the original work, p. 466, 467.

Note on Table A. Lengths over 10 m are given in m, over 25 m are not included.

In flexure by wind is assumed no resistance, but the seldom occurring edge pressure is taken as double the average compression, thus being 10, 20 or 40 kil per sq. cm, according to the material.

Note of Table B. The Table applies for a wind pressure of 120 kil per sq. m with the assumption, that in each cross section of the mullion the compression remains within the middle half. (Rise x of the pressure curve = $\frac{1}{2}$t, see Fig. 1151). It is required that the compression remains within the kern ($x=\frac{10}{36}t$), so that the values of D are to be multiplied by $\frac{9}{5}$. A continued reduction of the tabular values of D with even the best execution would lead to destruction, even before the limiting value of $\frac{1}{2}$ D is reached.

Application of the preceding results.

Limitation of the heights of mullions by tracery.

A. Length and dimensions of mullions. It has just been shown what limits of the height of a mullion of definite cross section are given by the danger of buckling, and even more by the window stress (p 495 and Table A). To observe these limits, it is simplest not to make the window excessively high, and to give the mullions themselves a sufficiently large cross section. But now in some cases an increase in the height of the window may seem worth making without too great strengthening of the mullions. The nearest means for this was already provided by the earliest Gothic, and was afforded by window tracery extending far downward, that has a practical value not only in an architectural but in more than one respect also (p. 500). A comparison of the late Gothic window (Fig. 1152) with the early Gothic tracery window (Fig. 1153), shows how markedly different are the lengths of the mullions in windows otherwise made of equal dimensions.

A second means of limiting the free length of mullions is afforded by a tracery arcade in the lower part of the window. (Fig. 1154).

Transverse stiffening of high mullions.

Also where these do not suffice, there remains as a third means an intermediate stiffening of one or even several places

above each other, as a b in Fig. 1155. These may consist of a horizontal mullion bar, of a series of arches with or without gables (Fig. 1155 b) or finally by a series of panels of tracery (Fig. 1155 c); in some cases a passage may extend across for watching the window at such places, that can be supported by an arch from the jambs or by special supports underneath, and so can contribute more effectively to the stiffening of t the window.

All these transverse stiffenings whether made by the middle division a b, the lower arcade at c d or by the upper area of the tracery at the height e f, have to prevent not only the buckling of the mullions but also the bending by the wind. Therefore the stiffening seen in plan (Fig. 1156) must act like a horizontal arch. The wind pressure against the mullions and glass will contribute to the stiffening, and at the point p of the stiffening (Fig. 1155) acts the wind pressure on the hatched area, which is easily calculated by multiplying the area of this surface by the unit pressure (120 kil per sq m). Thus each intersection receives its definite wind pressure, as K_1, K_2, K_3, in the plan, Fig. 1156. These forces combine in a line of support with the rise x, which can be followed further by graphics or calculation. For the last method a small example may find a place.

Example. A window 3.6 m wide may have 3 mullions averaging 0.9 m on centres, which are of cut stone and exhibit the cross section in Fig. 1150, 20 cm thick, 40 cm deep, 600 sq. cm in area, 11 cm length of kern. At mid-height the window has a horizontal bar of the same cross section (a b in Fig. 1155), and above and below it the free length of the mullion a e and a c is 5 m. The wind pressure on each intersection (the hatched area) accordingly amounts to 5.0 × 0.9 = 4.5 sq. m, and 4.5 × 120 = 540 kil = K_1 = K_2 = K_3 (Fig. 1156). Establishing the requirement that the line of support must remain within the kern, then also x = 11 cm, the moment equation for the half A B of the brace on which the pressure K_1 and half the pressure K_2, with the pivot M:- $H\,x = K_1 \times 0.90 + \frac{K_2}{2} \times 1.80$.

Inserting the valueu of x = 0.11, $K_1 = K_2 = 540$, the thrust in the brace is; H = 8333 kil.

This would produce in the cross section of 600 sq. cm an average compression of $\frac{8333}{600}$ = 14.7 kil, or with the assumed rise

= length of the kern a maximum edge comperssion being double, thus 29.4 kil edge compression per sq. cm. These pressures are still permissible with very good execution for quite strong cut stone.

For stone of less strength or a still greater breadth of window, the simple horizontal mullion bar would no longer suffice, and then would have to be chosen a stiffer arrangement, like two bars above each other and connected by tracery, which would then divide the work. A similar stiffening must be possible in the direction e f of the arcade c d at the lower end (Fig.1155), the pressure area of the wind is here somewhat less.

Since the cross bars have to act as horizontal arches, the end joints in them will be cut obliquely to correspond.

B. Loading of the mullions. Farther above (p. 494 and Tables A and B), there is shown how great a load the mullion can bear without too great stress, and on the other hand what minimum load it must have in order not to be broken by the wind. It is then to place this load skilfully on the mullion; it may either rest comfortably on the mullion or it may become effective when the wind tends to bend the mullion.

Loading by the tracery.

1. The preferable solution is always obtained when the tracery alone is sufficiently heavy to serve as a sufficient loading, which is the case in most Early Gothic tracery windows. The best construction occurs when the mullions and tracery are first inserted after the setting of the other masonry., so that an open joint remains between the tracery and window arch; while the falling out of the tracery is prevented by tongued connection, etc. (Figs. 1148 to 1148 c).

Occasional loading by the window arch.

2. Another case occurs when the tracery of itself is not sufficiently heavy for the mullions to be resistant to the wind, but it lies beneath the window arch, so that here usually no considerable transfer of force occurs, that on the contrary in wind the tracery can be strongly loaded. Naturally the weight of the window arch with the masonry lying on it must be at least so great, that it can be raised (Table B), but on the o other hand this upper mass will be increased without limit, s since it usually does not press on the mullions.

The correct relation of the different parts strongly depends

on the mode of execution. If the mullions have settled too little, the window arch will lie on it.(And the tracery and crush them if the load on the window arch is very great. See p. 501). On the contrary if the mullions have settled too much, so that between the tracery and the window arch is an open joint, and if this be only 1/2 or 1 mm thick, there occur in wind on account of the rigidity of the stone injurious movements and edge pressures, that in some cases may become damaging (p. 502). T Therefore in the construction according as it settles more or less later or at the same time, in the last case the tracery can even be utilized as a centering for the window arch, when it can be recommended that between them be inserted lead keys at small distances, which can prevent too great a transfer of pressure from above.

Just as in the manner described, the tracery under the window arch supports it, in windows of compound systems the smaller system stresses the larger one in the wind, which in a similar construction of both is also done with greater security. Since the strong cross section of the larger mullions are also carried up intthe tracery, so as its weight is advantageously increased, so that such a compound window is to be termed a favorable construction, whose general effect is mostly to be referred to Case 1.

Permanent loading by the window arch.

3. The third case consists in this, that the window arch with its load presses permanently on the tracery, thereby keeping this and the mullions under compression. This effect can be m more safely obtained, when the mullions and tracery are executed in a material settling less than the other masonry, and the window arch is turned over the compound tracery as a centering; now if the masonry settles at the sides of the arch, the arch itself will rest on the tracery, even hanging on it, which may even result in visible cracks. According to the proportion of the settlement will the arch represent only the little hatched portion of the masonry d f e (Fig. 1157) or the greater portion m a b c n; it may also be possible that commonly but the small part rests on it, but in wind if its weight is not sufficient, the greater piece of the wall participates.

At whatever inclination the lines m d and e n rise depends on the bonding of the masonry. The total weight of the arch

with the overload m d a b c e n in the calculation of the possible vault or roof loading must at least be so great, that the masonry in wind is not raised by the mullions (see B in T Table B) and must at most be so great, that the load on the mullion remains below the allowable limit (see P in Tamles A and B), otherwise this kind of stress in the mullions is not in place. The tracery loses very much in importance by this mode of construction, so that it is strongly restricted or can even be entirely omitted, and the mullions are then directly beneath the window arch as in mann works of late Gothic and Renaissance; thereby is produced the most tasteless expression of this mode of execution, which generally is least satisfactory in construction and taste.

The best solution always remains one sufficiently heavy, with simple or compound tracery, that does not require the aid of the window arch at all, or only needs to stress it in the urgent cases. The magnitude of the load of the masonry built above the window is then made entirely independent of the window itself.

Execution of the joints.

C. Execution of the joints and crushing. Joints are recently made in lime or cement mortar, where it is to be considered, that lime mortar settles more and remains plastic longer, while cement mortar quickly sets and thus its volume changes less. Which mortar is more suitable is to be decided only in each case, where the preceding considerations of the loading of the mullions afford the necessary indications. With high millions of cut stone in cement mortar in order to make slight chushing not injurious together with the resulting excentric transfers of pressure, it is strongly recommended to fill one joint with a lead plate, upper or lower, or better three joints, nameln the upper, middle and lower, indeed best so that the joint remains open at the outer and inner edges for 1/2 to 1 cm.

Too long and too short mullions.

Although stone also does not lack a certain elasticity, it can change its length only within moderate limits. If a stone bar be compressed more than 1/10,000 of its length, the stress generally considered as allowable is already exceeded, and if the shortening is continued, most stones will be crushed before the shortening attains 1/1000. By compression a mullion, when in consequence of too great length,is too strongly loaded, th-

therefore it can only avoid this overloading when the difference in length is very small. An elongation of too short a mullion can usually scarcely come in question, since with the slight resistance of stone and mortar to tension the joints will open very soon. Therefore it is briefly indicated to follow to a conclusion what danger may result to the mullions, if in consequence of crushing or of unequal settlement certain joints open.

Formation of open joints.

For windows with heavy and loosely set tracery (Case 1, p.500) an opening of the joints is not easily feared; if the mullions settle the tracery moves, so that between it and the mullions can no joint open, but a widening of the joint above the tongue before provided in this case in the groove beneath the window arch is injurious. Only when the tracery is firmly fixed between the jambs could also be formed an injurious open joint between tracery and mullions.

More to be feared is the opening of joints in windows, that assume a direct transfer of pressure from the window arch to the mullions ((Cases 2 and 3, p. 500), and indeed the opening between window arch and tracery or between tracery and mullions occurs, we shall briefly treat only the latter..

Tipping of the mullion at an open joint.

If no side forces act, the opening of the joint would be of no consequence, but when a strong wind occurs, even a very low mullion without upper load will tip on the lower edge B (Fig. 1158), since the pressure area of the wind is great and the weight of the mullion is very small. If the open joint Z is sufficiently large, the entire mullion may overturn, if any restraint by storm bars is absent, and indeed mullions with length l exceeding 10 times the depth t will overturn when $Z = 1/200$. More slender mullions with lengths of 15 t can fall if $Z = \frac{1}{450}$, and very slender ones occur with l = 20 t, even if $Z = \frac{1}{800}$. A mullion 6 m long and 40 cm deep (l = 15 t) might also overturn unhindered when the joint has at least $Z = \frac{6}{450}$, thus 1.3 cm or 1 1/3 cm.

If the joint be thinner, the mullion would not overturn without hindrance, for the edge E would rest against the upper surface as shown in Fig. 1158 a. If in the example given with the mullion 6 m long, the joint is only open 1/3 cm instead of 1 1/3 cm, the angle E would lie beneath the middle of the upper surfacea

But the mullion would not probably remain in this position, but would break in the next moment as in Fig. 1158 b. Then a line of support would be formed through the points F C B, which exerts a great lengthwise prssure (p. 495). Since the deges in contact could not transmit this pressure, the stone would crush at them, until a sufficiently large contact area is produced, (Fig. 1160 a), and then occurs no splitting off of the greater part (Fig. 1160 b), so that a mullion of very hard stone in the case would come to rest, and would remain protected from breaking. Whether the mullion returns to the original position after the stopping of the wind is doubtful, but in any case by repetition of these movements could easily be destroyed.

Breaking of the mullion at an open joint.

Far less dangerous is the open joint if the overturning of the mullion in its entire length is prevented, and the opposing thrusts of the ends are avoided by doweling (Fig. 1161 d), or by cutting the joints as in Figs. 1161 to 1161 c, or finally by grooving the storm bars in the upper and lower ends. If it is feared that the opening may indefinitely occur in the upper or lower joints, thus the displacement is to be prevented in the latter. If the settling of the mullion forms an open joint Z at top, so that the mullion can break as in Fig. 1159, for this is at least 4 times as great a thickness of the joint as for tipping as in Fig. 1158. The preceding mullion 6 m long must then have a play of 5 1/3 cm in order to free itself.But since great pressures are not to be considered, onln a moderate bending is to be expected, as shown in Fig. 1160. Then three joints open and aline of support B C G is formed, that again causes crushing of the angles furtunately (Fig. 1160 a), yet not without always coming to rest. When large pieces are broken off (Fig. 1160 b) there results a crash, and the stress at the points of contact ever moves toward the absolute limit of resistance, from which it results that open joints in the mullions of windows are not entirely inconceivable, unless by strong c continuous storm bars destriction is made impossible. Since the lack of the latter at other places has already been illustrated, it is advisable to devote the necessary attention to the construction of the mullions. Most reliable will always be windows with heavy tracery inserted in over the mullions in grooves, as to be emphasized later. If further the mullions, as in many

Early Gothic examples, consist of a single strong stone, that is prevented from tipping by anchoring beneath the tracery, t then naturally is thereby met all danger most effectively. But also the other arrangements with careful execution will show themselves permanently allowable, unless great pressures occur to loosen the entire structure of the building.

2. Arches and window tracery in general.

Development of tracery.

The word Masswerk (tracery), i.e., measured work, is in contrast to foliage or to ornament formed by a free hand, and it accordingly denotes the transition from purely structural to ornamental forms. According to the place and the tendency of its employment the former or sometimes the latter element predominates in it.

Tracery consists of geometrical ground forms arranged beside or inserted within each other, that either retain their simplicity or are more detailed by a combination with other forms. Perhaps in no other form is expressed the ground law of Gothic art:- that all must serve the highest purpose and every part be subordinate to the whole, most clearly in the tracery, that even makes abstract mathematical figures serviceable by a detailing, that only demonstrates more plainly the essential peculiarities. It is like geometry brought to life.

But the tracery is no mere surface decoration like the Greek fret and the Moorish interlacings of lines, but by means of its members having depth it is a form in space, an independent wall, that may be either perforated or closed. Since Gothic art proceeds to form the entire architectural mass with a strongly c connected skeleton, or according to the modern expression, to substitute strength for mass, then in tracery the skeleton consists of the members enclosing the different figures. The elastic strength of the lines replaces the masses omitted in the perforated or sunken panels, and the constructive principle of the entire architectural work is thus reflected here at a small scale.

But in a neglect of this structural importance lay a danger of misuse. The corporeal tracery became a surface decoration, that indeed is very rich and charming, but according to an estimate of its value, it can only be placed in the same line with that Moorish surface work. At the end of the middle ages

all surfaces began to overgrow and frequently to conceal the structural skeleton in a very reprehensible way. This dominance was so general and the charm of the tracery was so vern captivating, that even the interrupting Renaissance could not at once free itself. Thus we see the most varied ornamental tracery conceived with the greatest refinement even in the midst between Tuscan columns, mouldings like the antique and balustrades.

The most important applications of tracery are the following.

2. For opening parapets, the so-called balustrades.

1. For connecting at top and loading the dividing mullions in glazed windows and open arcades.

3. For characterizing those parts of the wall, that are removed from the effects of great pressures, like window parapets, gables and window gables, etc.

The most important problem is to be fulfilled in the use first mentioned, and there has it also found its fisst and richest development.

Grouping of the openings.

The first germ in the development of window and arcade tracery was already formed, when several arched openings adjoining were combined in a group. The opportunity for this was given on the one hand by the difficult opening of very thick walls, on the other by the division of a continuous wall into vaulted bays.

If there were openings in thick walls without glazing, like the windows of a tower or the arcades of a cloister to be grouped together, in the Early Christian and Romanesque periods men first helped this by placing cap-like stone beams transversely on the capitals of the dividing columns, whose length equaled the thickness of the wall, and besides instead of a single column were placed two, one behind the other. For the particularly thick walls made necessary at first by the introduction of vaults, the end was no longer attained well by this; the cap stones became very long and the columns appeared little, but the soffits of the arches above them were heavy and like tunnels; thus the latter shut out much of the light and what was worst, the slender columns were loaded beyond reason by the heavy masses of the upper walls. The evil first mentioned was opposed by corbels and blind arches above the capitals, as shown by Fig. 1162. (Abbey church at Laach). The great stress in the

columns was not relieved thereby. This could first occur when the separate arches were replaced by a great and common blind arch extending over all openings, this passing through the entire thickness of the wall as a relieving arch. Then the wall beneath this arch could again be reduced in thickness and even placed on a single row of columns, omitting the cap stones (Fig. 1163, cloister at Riga, beginning of 13 th century).

Thus already for a continuous wall, whether it supported vaults or not, the great thickness led to combining the openings, and the introduction of cross vaults with buttresses dividing the wall into separate panels, indicated this so much the more.

Best can be followed the influence of vaulting in the treatment of windows in the middle aisle of the basilica. The basilica with beam ceiling shows a continued series of separate windows, whose spacing often had no relation to the divisions of the lower arcade. By the use of cross vaults the windows must be regularly placed in the side wall. A single window in each bay would generally afford too little light, so that groups of two or three others must be placed beside each other (Fig. 1165), but the Romanesque churches then retained heavy and deep jambs for small widths.

Relieving arch above several openings.

As an expedient was here again presented the relieving arch combining the windows, under which the thickness of the wall could be reduced, as this could serve as a separate arch, or it could take the place of the side arch passing through the entire thickness of the wall, and this was so much more possible in the beginning Gothic, since the supporting mass was t transformed to the pier (Fig. 1165 a) as the wall under the relieving arch no longer had to support anything, the piece of wall remaining between two windows could also be reduced in width, and the windows moved near each other (Fig. 1165 a). When in this manner two ordinary splayed jambs (Fig. 1166) were brought together, there remained between them a thin mullion with the plan of Fig. 1166 a, or if two windows flanked by columns came close together (Fig. 1167), there finally disappeared entirely the flat piece of wall (Fig. 1167), columns I and II were combined in a single column, and the remaining bit of the wall became the mullion indicated in Fig. 1167 a. Thus was formed in an entirely natural way the typical plan of a mullion

in Figs. 1166 a and 1167 a. In the plan of Fig. 1167 a men were led to insert the necessary intermediates to receive the rebate, when glazing was to be added in arcades with coupled columns (Fig. 1162 a). With the closely adjacent window openings were directly enclosed by the side arch (Fig. 1165) or by a seperate smaller relieving arch when they did not occupy the entire length of the bay, has already been stated.

Perforating the tympanum of the arch.

If now two or more openings occur beneath a common arch, there remains a tympanum wall above them (Fig. 1163), aod to open this was naturally the next step indicated, and for this purpose could be employed one or more circles or some other geometrical figure (trefoil, quatrefoil). Fig. 1164 shows a perforated tympanum from an entirely Romanesque cloister at Königslutter, and Fig. 1168 one from the Early Gothic cloister at Fischbeck (both from Hase's Niedersachsen). At the window from the collegiate church at Wetter (Fig. 1169) three trefoils tolerably close together are employed. Preferably the tympanums were made of rubble or brick, the material determining the character of the openings. Even this first stage of the development of tracery does not lack its special charm. If the openings were not glazed, they could be most simply cut with rectangular jambs (Fig. 1170). The glazing may lie flush with the inner surface in the little rebate m, but chiefly is in the middle of the jamb, that shous the profile in Fig. 1170 a to c, elsewhere u usual on the mullions.

Tracery bars.

The openings soon increased in number and size and adjoined each other, so that they left little of the surface of the tympanum beyond them, and thus the jambs were so close together, that also the profiles shown in Figs. 1166 a and 1167 a originated here. These profiles then continued as curved bars around every opening so that they passed into each other at the points of contact (Fig. 1171), and also with the section m n of the same cross section in Fig. 1171 a exhibits a favorite and freer cross section n n of the bar. But thereby was completed the p proper devilopment of the tracery, where a single enrichment was yet added for great windows the arrangement of the main tracery in this inserted subordinate tracery, whereby in the tracery and the mullions equally originated the combinations

of the larger and smaller systems.(Figs. 1262, 1268).

Before we pass more fully to the window tracery, it is necessary to treat the different forms of the tseatment of certain ever recurring forms of tracery, such as polyfoils, cusps, fish-bladder, etc., in a connected form by themselves.

Romanesque forms.

Besides the simple round arch, Romanesque art very frequently employed both in arched friezes as well as openings for light and doors, the sportive trefoil arch (Fig. 1172) composed of several circular arcs, that besides a round also soon showed a pointed top (Fig. 1173). Likewise occurred in place of circular openings (Fig. 1174) cross-shaped or those of purely ornamental form (Fig. 1175 from Naumburg, according to Redtenbacher), but more commonly appeared trefoil, quatrefoil and p polyfoil openings (Figs. 1176, 1176 a, 1176 b), that are named according to the number of circular arcs, trefoil,(Fig. 1176 b), quatrefoil (Fig. 1176), cinquefoil (Fig. 1176 a), or generally polyfoil. The jambs were cut square or surrounded by mouldings, when the projecting angles or the cusps frequently had rich ornamental terminations. The openings were frequently cut through single slabs of stone, or where this was impossible, men sought to make the ashlars as large as possible, and the joints were mostly cut square across the mouldings. In Figs. 1172 to 1176 are given various modes of jointing.

Early Gothic forms. Cusps with full bar moulding.

All these forms were first transferred to Gothic almost unchanged. Then when men began to separate the perforated slabs of the tympanums into tracery bars, the outlines of these figures were constantly suffounded by the bar moulding. The angles or cusps were also formed by the complete bar moulding (Fig.1177). Forms of tracery of this kind that combine trefoil arches and polyfoils in the most varied ways are particularly common in the second quarter of the 13 th century in use. Figs. 1235 to 1239 and 1241 give examples of them. About the middle of the 13 th century appeared in many places almost contemporaneously the proper cusp, that does not form a separate bar, but grows sidewise out of one as shown by Figs. 1178, 1179, 1181, etc.. The entirely free trefoil arch (Fig. 1177) there returns to the pointed arch in which the cusps are added in the form of trefoils (Figs. 1178, 1182). To this transition may have con-

contributed the fact, that the free bar in Fig. 1177 in appearance and reality could be more easily broken, and did not seem as well suited to transfer stresses lengthwise. On the contrary this purpose was attained better by greater lengths, when the bar was continued also in the dotted line, and even at the middle, which usually broke first in buckling, there was obtained doubled dimensions.

Both on the pointed arch as on the trefoil arch enclosed by it could be carried around the full mullion moulding, as shown in the left half of Fig. 1178. But the cusp of the trefoil arch then seems rather dry and heavy, but will already become more graceful if the width of the moulding is somewhat reduced, so that the front surface n is only 1/2 or 2/3 the breadth m of the pointed arch, as in the right half of Fig. 1178. In the space or spandrel between the pointed and trefoil arches, the sides form a triangular sinking a b c or in some cases a free opening d e f remains, and the corresponding cross section of the cusp are shown in Figs. 1178 b and 1178 c. The opening in the spandrel is sometimes avoided by the insertion of a flat panel, or it is enclosed by flatter chamfers intersecting in a line (Fig. 1178 d).

Cusps of less thickness.

But the same depth of moulding on pointed and trefoil arches belongs rather to unusual forms, as just explained by Fig.1178; as a rule the inserted trefoil arch shows a moulding of less depth (Fig. 1179). The origin of this solution may eventually be referred to those Romanesque portals that instead of the solid tympanum have a trefoil arch inside the soffit of the arch. In the nave of the Strasburg minster is found the Romanesque round trefoil arch inserted in a pointed arch (Fig. 1180a), at other places is found already at the same time a pointed t trefoil arch in the pointed arch, but thereby is created no p principle; the cust is shown in Fig. 1179, and as it came into use about the middle of the 13 th century.

Allied to the solution in Fig. 1179 is the form of cusp in Fig. 1181, and in both the profile of the cusp already exists in the profile of the mullion, and Fig. 1181 exhibits the peculiarity that the surface a b extends directly into the spandrel. In the forms of Figs. 1182 and 1182 a the moulding of t the cusp is no longer carried down on the mullion, but on the

contrary in Fig. 1183 the cusp projects freely from the side of the mullion.

It is the same Late Gothic mode of treatment, that shows itself in the springing of the rib from the pier (p. 99), and t that frequently leads to the intersection of different mouldings. likewise in tracery occur rich penetrations, and thus in the tracery on the buttresses of the castle church at Altenburg, the cusp arches composed of fillets and cove project from the mullion consisting of a simple round.

Ending of the cusps.

If the cusps project but little, they terminate in an obtuse angle (Figs. 1181, 1182). Long cusps would have an acute angle, which is ugly and fragile, and therefore this is replaced by a wider end (Figs. 1183 a, 1184), when the radius of the arch is so shortened that the arcs do not intersect but leave a space between them.

This broad cusp that already occurs in the earliest tracery, especially on polyfoils and wheel windows, can be cut off square in the simplest cases, about on a line joining the two centres (1184 a, b, 1185). If it is extended farther, the arcs d diverge again at their ends (Figs. 1184 c, 1186, 1187), and c can again be cut off square, be made acute by two oblique surfaces (Figs. 1186, 1187). The moulding of the edge may stop dead at the end (Figs. 1184 ., 1186), or may be returned around it (Figs. 1184 b, c, 1185, 1187). Long projecting cusps extending from broad chamfers or coves may occur, where at the end is increased not only the width, but also the thickness. (Figs. 1186 to 1188).

The cusp may have a richer termination by a head (Figs. 1188, 188 a) as in the church at Haina, by a heraldic lily (Fig. 1199), numberless examples of which are found in the earliest and latest times. Forms of the latter kind are especially suitable for ornamental arches of a polyfoil or trefoil.

Sometimes the cusps extend so far that two opposite ones are produced (Fig. 191). These are exaggerations in which the late time is not poor.

Cusps of the second order.

To the cusps preferred in the later time also belong the compound cusps, formed by inserting small cusps again in the main cusps (Fig. 1192), which mostly grow out of the main bars, like

the ordinary simple cusps. To be distinguished from these cusps inserted in each other are the frequently curved Early Gothic forms of tracery, in which the large and small cusps are formed by the complete bar moulding in unbroken course (Figs.1238,1241).

Detailing the trefoil arch and cusps.

Trefoil arch.

The Romanesque trefoil arch in its most severe form shows at the sides two quadrants with a semicircle in the middle (Fig. 1193), and the latter may be stilted (Fig. 1193, right). Moreover there also frequently occur arches with much more acute angles projecting internally (Fig. 1194), the radii of the three arcs are mostly equal, since greater differences in their lengths do not please the eye, and in rich mouldings introduce difficulties at the intersections (more on those below on Fig. 1202). Especially great becomes the difference of the radii, if the two side arcs form parts of a semicircle according to Fig. 1195, as the form produced thereby with a round middle arc is not expressive. On the contrary with a pointed middle arc it is quite possible to draw the two side arcs as parts of a semicircle, and then use the same radius for the upper pointed arc. Figs. 1196, 1193 and 1198 give three different arches of this kind, where the parts of the arches have the s same radius. Fig. 1196 has the effect of a somewhat low separate trefoil arch, the upper centres being on the semicircle; in Fig. 1197 the centres are raised to the height of the crown of the semicircle, and in Fig. 1198 they are raised to far that right angles are formed at the points m and n. The last will always be attained when the distance of the centres d and e frog c equals the chord a f. The form in Fig. 1198 must represent the extreme limit for the slenderness of the middle arch, it is satisfactory in a certain measure, if the side arcs are stilted by a g to have equal rise.

It is indeed permissible but not at all required, to strike the lower ones from the same point c, or any two chosen points c and may be employed (Fig. 1198), likewise it is not necessary to make the distances between the upper centres d and e equal to the radius, as occurs in the selected example, they can be placed nearer or farther apart, even the equality of the radii is onln advisable, but is not to be termed necessary. Moreover the simple trefoil shape not enclosed by an arch allows the

greatest freedom, and it is not forbidden to draw it in free curves without the use of compasses.

Cusps in pointed arches.

Far more restricted are naturally the trefoil arches that by the insertion of the cusps are formed in an enclosing pointed arch. So far it does not have to dominate the latter, but it also affords it the freest play; the sole rules that it is recommended to carry out are contained in the two next requirements.

1. That the cusp arches join the principal arch without breaks at the transition points (a, s, w, v, w) but tangentially.

2. That the radii for the two halves of the cusp are equal.

In Figs. 1199, 1200, 1201 are represented some examples of the construction of cusps, which all have in common that they satisfy the indicated requirements.

The first condition is always fulfilled if the centre of the cust arcs,(2 or 3) lies on the straight line drawn from the c centre of the principal arch (1) to the point of transition. Thus in Fig. 1199 the point 3 must be on the line 1 s, and likewise in Fig. 1201 the point 2 lies on the line 1 u, etc. From the second condition follows, that the centres 2 and 3 of the cusp are on an arc struck from the principal centre 1.

If one does not obey the latter, the concentric profiles intersect in a curved line after the manner of Fig. 1202, whereby the cusp appears curved. If also the latest Gothic did not recoil from such peculiarities, but often sought them, the better period justly avoided them.

Fig. 1199 shows a principal arch with small rise, the radius 1 s being only 2/3 of the width a b. The cusp arcs that first join the principal arch at the ends a and s, are struck with a half radius, thus $s\,3 = a\,2 = \frac{a\,1}{2} = \frac{a\,b}{3}$. The cusp a m s formed thereby is pretty stumpy. By reducing the radii, thus transferring the centres to 2′ and 3′ longer cusps are produced.

Fig. 1200 shows an arch whose radius equals the width (inclosed by an equilateral triangleU. The very stumpy cusp a m s is drawn with a radius = half the width, and the arc a m is thus a part of the semicircle about the centre 2. The centre 3 correspondingly on the middle of the line 1 s. Now if the radius of the cusp is made only 1/3 of the width, then $2'a = \frac{1}{3}\frac{a}{}$, this would extend to the middle o and there join the opposite cusp. Within these limits 2 and 3′ will thus have to be located the

centres of the cusp. About in the middle between both is found a point 2″ or 3″, that produces a cusp right-angled at the front point m″. (Accurately calculated the radius a 2″=0.414 × a 1).

In Fig. 1201 the cusps do not extend the entire length of the principal arch, but on the left half they leave the principal arch at the points u and v, so that the same distances a u and v s may remain free above and below. On the right the cusp indeed extends down to the end point b, but it leaves the part s w free above. Raising the principal arch the distance b g the cusp again lies more in the middle of the arch. Forms like that shown in Fig. 1201 chiefly belong to Late Gothic.

The lines given in Figs. 1193 to 1201 give the clear area of the openings, the members are concentric around them and intersect in the way given above. Drawing them presents no further difficulty, so that it can be passed over here. Also for the case that in drawing one does not start from the clear opening, but from the middle line of the bar (Fig. 1234 a), most of the given forms of cusps are usable.

All these constructions, both the entire scheme of the tracery like the cusps, can be frequently modified and best so, if made after a previous freehand sketch, only serving to fix the character of the latter, which is least successful, if one scrupulously adheres to a geometrical development. Certainly this affords certain starting points, but thereby some part is encroached on, which is especially true of the interspaces, since they can unconsciously be departed from, and the compasses be set a little away from the geometrical point, even if not otherwise slightly reducing the width of the member of the bar a little at places, as then usually the cause of the magnificence, which is to be sought in a mediaeval work in tracery, before one belonging to restoration there or otherwise copied.

Drawing the polyfoil.

All that has just been said of the drawing of the cusp in p pointed arches may be applied to central figures of every kind.

Cusps within a circle.

When the Romanesque polyfoil is enclosed by a circle as those shown in Figs. 1176 to 1176 b, then is completed the transition to a tracery of central form, the incurved foils of the polyfoil become inserted cusps. This course of development then clearly appears, the curves of the cusps entirely occupy the in-

interior of the circle, and only in a few cases does the latter remain visible between the cusps struck with small radii, like the pointed arch between u a and v s in Fig. 1201. The cusps are either inserted in grooves in the enclosing circle, like the tracery in the window arch (Fig. 1148 b), or they are wrought in one stone with the accompanying moulding.

Laying out the cusps in the circle is based like that of the polyfoil on the simple division of the circle, as to insert 3 3 cusps the radius is laid off 6 times in the circumference and these points are connected, and the centres of the curves of the cusps lie on the diameters thus obtained. Their distance from the centre of the circle, C a in Fig. 1204 is laid off from C f half the width of the cusp b a on each side, parallels are drawn to C f and on C c is sought the centre for the cusp arches touching these lines and the great circle.

If the cusps are to be pointed as in Fig. 1204 a, the choice of the centre is made according to the degree of its acuteness, and can be limited to between the points a and b. In general it is better not to make the points too long, so that the centre is placed nearer a, as the excellent effect of the tracery in the north portal of the cathedral at Rouen shows.

Entirely in the same manner are obtained 4, 5, 6, etc. cusps. Fig. 1205 shows the insertion of 4 cusps or the formation of the quatrefoil, whereby according to the form that the cusps are to receive, the choice of the centre may be made betwhen a and b.

Cusps in trefoil arch:

The insertion of the cusp in the trefoil may occur in very different ways as shown in Fig. 1206. First is the construction of the trefoil by three semicircles to be possible by 3 semicircles through the middle points of the sides of the triangle (thus a in Fig. 1206), whereby is obtained the form of the trefoil in Fig. 1207. The cusps then project little and correspond to the cusp curve in Fig. 1200. A form like Fig. 1207 a results if the centres of the arches in Fig. 1206 lie on the circular arc a d between a and d, thus about at e.

But both cusp curves can also be struck from one point and the cusp still remain pointed as in Fig. 1207 b, if the centre is placed at about f in Fig. 1206, and finally the form shown in Fig. 1207 c with a square cusp may result from a centre pla-

placed at h in Fig. 1206. Figs. 1207 to 1207 c show what different effects can be obtained by such slight modifications. The insertion of doubled cusps in these Figs. can occur in just such varied ways.

The insertion of cusps in the square is shown in various ways in Fig. 1208.

Cusps in the square and in the quatrefoil.

In the right half the middles of the sides of the sjuare are connected, and in the diagonal square thus formed is drawn a circle, the arc d c is bisected at f and from f etc. are struck the arcs of the cusps. Between the points d and f can the centres be moved to obtain a different shape of the cusp.

The left half of the Fig. shows the form of a square cusp. There is laid off from the line bisecting the square half the width of the intended cusp on both sides (Fig. 1204, parallels are drawn to C g that cut the sides of the square at i and k, then is drawn the line i k, bisected at l, and from l with a radius if the side of the square is struck the arcs of the cusp.

Fig. 1209 shows acute and blunt cusps in the quatrefoil, with centres indicated in the drawing. In some curves are inserted cusps of the second order. Further statements on the different possible positions of the centres may be omitted.

Various circular panels.

all previously shown forms of cusps and polyfoils can be inserted similarly in the circle. But a different mode of filling this is obtained either by the division with bars placed radially, which may then be beset by cusps, or by the insertion of circles as in Fig. 1214, or of other geometrical figures. Simpler forms of this kind are shown in the later succeeding figures of windows and rose windows.

The construction of Fig. 1210 results simply from the inscribed equilateral triangle, as indicated by the inserted aiding lines.

In Fig. 1211 are inserted 4 equilateral arches produced by 4 equilateral triangles

In Fig. 1212 8 square arches are placed in the circle. In order to draw them without long trials, there is employed a s subordinate Fig. 1212 a, in which is laid off a desired length a b on a horizontal line, and with thes length is struck from a and b the intersection c, a b is bisected at e, e c is drawn

and divided in three equal parts, marking the first point d, then on a b is constructed a square a b f g, from d is described a circular arc that passes through f and g, and c e is prolonged to the point h on the arc f g. Then the circumference of the circle in the main Fig. 1212 is divided in 6 parts, and to these divisions are drawn the radii i G, k C and l C, so t that only from i is to be drawn a line parallel to a h in the subordinate Fig. 1212 a, which cuts k C in m, to find an angle of the square arch m n o p. The other points are found accordingly. The arcs of the square arch can be found by making from p and n with a radius i C an intersection s, and from this is struck the arc p n.

Fish bladder (vesica) and intersections of tracery.

Fish bladder.

Besides and according to the just explained filling of the circle by inserted geometrical figures, that with the fish bladder appeared in the 15 th century. Fig. 1213 exhibits the filling by 3 circles, that both touch each other and the great circle. If the dotted parts of the lines are omitted, there result 3 fish bladders. In the same manner are formed within the circle two fish bladders from two inserted circles, and f from 4, 5, 6 circles are as many fish bladders.

Fig. 1214 shows the insertion of 5 circles. The periphery is divided into 10 parts, from the dividing points are drawn radii a C, b C, and these are produced to cut the tangents at f in g and h. Then is drawn through h a line to the opposite bisecting point of C g, so that the centre i is given by the intersection of the latter with the line C f.

On the proportion of the fish bladder to the width of the m moulding will only be said here, that as a rule the assumed moulding of the tracery goes around in the circle and also in the fish bladder. According to its proportion to the diameter of the circle, also to the position occupied by the circle in the entire tracery, is therefore the arrangement of the fish blader, so far that its number must diminish when the diameter is less in proportion to the width of the moulding, and conversely.

Fig. 1215 then exhibits the insertion of cusps in 4 fish bladders in different ways, which may likewise occur for 2, 3 or more. First the line of the scheme is paralleled by the width of the moulding taken from the bar, and the cusps are then con-

constructed either on a line drawn from the centre c to C in the semicircle, as shown in the right upper half of Fig.1215, or in a greater circular segment, that is formed about according to the left upper half on the line c′c″ and the prolongation c′d of the line c′C. Then there lies one centre on the line c′e, the second on c′f and the third on the bisecting line cwg of the arc e f.

All previously shown fish bladders end with a round arch.On the contrary Figs. 1216 to 1218 exhibit the form of the pointed fish bladder.

In Fig. 1216 are first drawn the lines for dividing the circle into three equal parts, thus a c, b c and d c, then each of these lines like c d is divided into three equal parts, and from the point 1 of this division lying nearest the centre of the circle is struck arcs with the radius 1 d, which thus forms the equilateral arch e f g about the centre. The points 1, 1 and 1 are joined by straight lines, and these are produced beyond the circumference of the circle, thus from 1 to h, and t then are found on these lines the centres k, from which is struck the arc i l with the radius 1 a.

In Fig. 1217 are inserted 6 fish bladders. First are drawn the lines for hexapartite division, then a c is bisected at b, c b is drawn from c to d, etc., and then from b with the radius a b is struck the arc a d, likewise from the points d, etc.Now d b is laid off from d to f, and from f is struck the arc d b, and the process is repeated for the other points.

Fig. 1218 then shows the insertiog of 4 fish bladders. First are drawn the lines a b and c d for the division in 4 parts, then from b is laid off the distance b c to e, then f e from f to g, h and i, the sides of the internal square e g h i are drawn and produced to the other side, thus to k, l, ect, from h with radius h b is struck the arc b g, from g the arc c e, then from the intersection of the latter with the lines h k and g l, and thus from the points m and p the arcs n h, g o, etc., completing the construction.

Intersections.

Varied forms result from the intersections formed by the curves of the fish bladders. Such forms are shown by Figs. 1219 to 1225, whose construction results from the lines indicated, and which characterize the last period of Gothic art, the last

times of the 15 th and the beginning of the 16 th centuries.

In the filling of circles shown above, of the middle period by inserted geometrical figures these alwans assert a certain independence, if they already subordinate the principal form, and which is expressed by the inserted cusps. For the cusps really and essentially denote the limits of further divisibility. There indeed occur certain forms, that appear to contradict this rule, like that represented in Fig. 1222, where the circle with 4 cusps is divided in 4 parts by a cross again having cusps, without the importance of the rule being lessened thereby, for the cusps placed on the circle are just as well related to one of those forming quadrants, differing only from them by the greater radius of their arcs.

The adoption of the fish bladder first violated the principle of the independence of the separate figures. The fish bladder commences at its head as an independend form, but loses this character at its ending, which like a resolution corresponds to a disappearance. Now the cusps also had no longer a justifiable existence, and therefore were omitted, and all emphasis was placed on an exaggerated and labored bending together, and even intersections of the endings or rather of the bars forming them. In the increased intersection of the latter men further sought a substitute for the voids left by the omission of the cusps. But since the extension of these crossing bars was no longer restricted by any organism, and finally all threatened to overrun or to lead again into the old intentionally abandoned paths, there remained no means then to cut them off abruptly as done in Figs. 1219 and 1223 to 1225.

Gothic art represents in its works the supremacy of the cross over everything in existence. We do not say that men sought s such a symbolism everywhere, it grew up as it were. The basal form is that of the cross and includes in itself all possible conceivable forms, geometrical as well as freehand. The system of vaults is based on a twofold intersection in the direction of the sides as well as of the diagonals, and shelters all found beneath it. What is the pointed arch itself but a cross f formed by two parts of arches intersecting at the crown. It includes all forms in itself, the closed geometrical, subordinated to each other according to their location, magnitude and form, and the spaces as if serving for joining. To such a part

is given a location, each one must serve and over all together stands the cross. This subordination must first yield to the search for greater variety, instead of forming the whole for the parts and these from the different units, the latter are first brought into direct relation to the whole. While in Early Gothic works the polyfoil is the depermining unit dominating the entirel form, leaves a certain justification of the interspaces as serving as a still suitable form, these are reduced in a measure that they formed closed geometrical figures from the polyfoils, which are undisturbed by the spaces and enclosed only so much area, as they could no longer use themselves. Thus the tracery of the middle period consists of closed geometrical figures like trefoils, quatrefoils, circles, etc., and the sometimes considerably crushed interspaces. It was also near to open the former as well as the latter, and thus at first to form only occasionally occurring fish bladders (as Fig. 1255 a shows), until finally this principle of joining e everywhere replaced the isolation of the geometrical figure, all difference between the stipulated and conditional figures disappeared, and finally all was simply formed by the intersection of its limiting lines.

3. Tracery with simple Mullions and Wheel Windows.

Mullion windows of Early Gothic.

Plan of mullions.

For reasons of stability and admission of light the cross s sections of mullions received great width and small thickness, as stated above (Figs. 1226 to 1228). The most natural and simple plan is accordingly a rectangle with angles chamfered to further favor the admission of light. Fig. 1226. The glaqing, p. 468, almost always is in the half depth of the mullion in a groove, see left half of Fig. 1226 or in a rebate, Fig. 1227. The usually narrow rebate is not less that 10 to 15 mm wide and extends on half the mullion by a chamfer, Fig. 1226 right. Adjoining the glass is a flat n b in Fig. 1226 or i k in Fig. 1 1227, which at least must be wide enough for the putty and the fastening tacks. From the point b may the profile diminish, so that only a width a c of the mullion remains outside and inside, that is 1/4, 1/3 or at most 1/2 of the entire thickness b d. Instead of the plane chamfer, Fig. 1226, there occurred already early a more or less flat cove, Fig. 1227 above, and the cove

can also extend in a flat e g (Fig. 1227, bottom left), or sometimes it is cut deeply into the mullion (Fig. 1227, bottom right).

Far richer and more graceful is the effect of the mullion, if a little column is formed at both edges, Fig. 1228. Io the early period almost without exception this bore a capital beneath the beginning of the tracery, that was particularly unavoidable if the profile of the upper tracery differed more or less from that of the mullion (Fig. 1233). In the middle Gothic the capital and then also the lower base were omitted, and the column became a projecting moulding that branched into tracery above. In the first time the column is indeed found detached as a separate and projecting round set on end, but it is mostly wrought in the same stone. The column may lie before a flat of the mullion (Fig. 1228, top), or it may intersect the chamfer or cove (Fig. 1228, bottom).

The effect of the entire mullions is increased, the more the little column dominates the thickness by its diameter. That t the projection of the capitals shouldnot come too close to the glass, the depth of the mullion is to be increased, so that it may be nearly fourfold its thickness. Even then the little column has a clear effect, if it be separated from the rest of the profile by a straight or coved neck (Fig. 1228 a).

Instead of the round without capital a prismatic member may also be before the mullion, Fig. 1229, that likewise continues unchanged in the bars of the tracery.

When the tracery has no projecting cusps, the simple moulding in Figs. 1226 or 1227 may follow without change all the curves of the tracery. These cross sections also correspond very well to the elevations of Early Gothic tracery in Figs. 1234 to 1239 and 1241, although these could also be formed with richer profiles. With the existence of separate cusps as in Figs. 1240, 1242, care is to be taken in the development of the profile as previously done in Figs. 1178 to 1183. The Early time desired the cross section of the cusp to be already expressed in the lower mullion, wherefore for this purpose the profiles in Figs. 1228 and 1229 are well suited, in which the section of the cusp is indicated by hatching. In the later time men did not hesitate to permit the cusp to grow out of the simple mullions in F Figs. 1226, 1227.

But where in the older works thefforms of cusps occur with

a simple section in Fig. 1226, there the parts beset by cusps are changed to correspond, and thus on the windows of the sacristy of S. Elisabeth's church aat Marburg, the sectionof the mullion in Fig. 1226 in the trefoil with cusps has an addition indicated by the hatched part, that must indeed grow out of the mass of the dividing arch, since capitals do not exist. B But the last case proves, that the growth was nowise unknown in the Early time, but only preferably avoided.

Elevation of the window.

The general form of the elevation of the window in two divisions consists in this, that the middle mullion is connected by arches with the two jamb mullions, and the space remaining above these division arches and within the window arch is filled by a circle or another more or less complex form.

The simplest of these arrangements is the circular filling, yet this permits several substantial variations, that are outlined in Figs. 1230 to 1232.

In Fig. 1230 the main lines of the division arches join that of the great window arch and the radius of the circle filling the disk is determined by the heights of the arches.

In Fig. 1231 the circle is struck with a greater radius, and the main lines of the division arches are therefore lowered under the great arch.

In Fig. 1232 is found the same proportion of the main lines, and there is only the difference that the main lines of the separate arches do not join as in Fig. 1231, but merely pass by each other. This difference isclearly expressed in the cross section at ab and f g.

The last arrangement is peculiar to Early Gothic, and is found applied on different plans of mullions, as in the Liebfrauen church at Treves, the church of S. Elisabeth at Marburg and the church of the monastery of Haina. It makes possible, as well be seen later, many complex forms, while it brings the system of mullions to an independent termination, and allows a varied and more suitable form for the spaces between the great arch, division arches and the circle. But then it is especially justified, if according to the section represented in Fig. 1233 of the round extendind around the tracery proper has a smaller radius, than that accompanying the mullions and jamb arches, so that the two intersecting arch mouldings b c d and f g h rest

on the capital of the mullion, hence the hatched portions form projections on the capital, and the cross section at f g in F Fig. 1232 receives the form shown in Fig. 1233 a.

The most common scheme for the window of two divisions is f formed by Fig. 1231, that forms the basis for many variations. First may the circle be beset inside by round or pointed arches, indeed by 3 to 8, while the division arches are simply pointed. Merely the simple contrast of the simple division arches to t the rich ornamentation of the great circle exerts a certain charm. Fig. 1234. Instead of the simple pointed arch may be employed the trefoil shape for the division arches, as in the Early Gothic polyfoil windows in Figs. 1235, 1236. After the middle of the 13 th century very frequently occur division arches with inserted cusps, as the tripartite window from the cathedral at Erfurt shows in Fig. 1240, that likewise affords an example of a pointed polyfoil in the circle.

Laying out the tracery.

To lay out a tracery window, two different procedures may be employed. According to the first there are drawn the middle lines of all mullions and bars, and the width is then laid off at both sides; according to the second there are first drawn the clear openings of the main forms, the widths of the bars are laid off and then the clear openings of the subordinate forms. In some cases the two methods may be combined; it is always well first to determine the main proportions by a free-hand sketch, and to adapt the geometric skeleton lines to this. Since where two bars pass into each other or intersect, there is formed a junction that shows the normal profile at the narrowest place, but in no case can be weaker than that. The least fault in this has an effect disturbing in the highest degree.

Window in two divisions with circle filling.

Some Early Gothic windows may now be mentioned with a brief statement of the procedure in laying out. A frequently occurring window, that on account of its natural development and its noble simplicity can almost be taken as the ground type of the Early Gothic tracery window in two divisions as shown in Fig. 1234. Its effect is intimately connected with the size of the upper circle of tracery, which on its own part is again in a certain dependence on the proportion of the height of the window, the breadth of its jambs, the dimensions of its moulding

and the requirements of glass painting, in general may it be assumed, that the tasteful effect increases with the size of the circle, as shown by . comparison of Figs. 1230, 121 and 1234. In the last Fig. the circle extends down below the base line a b of the window arch, while on the windows of the choir at Rheims even the centre c is moved down to about the height of the base line a b of the arch. That even with this exaggeration the window at Rheims is still tasteful is to be attributed to the fact, that the circle member does not grow with the jamb member, but is inserted in that, whereby the size of the circle has suffered a slight restriction.

The middle lines of the bars are drawn in Fig. 1234, they join each other at the contact points m, t, etc., whereby the complete growth of the members is expressed. The centres a and b of the window arch in this case are placed on the middle of the mouldings, and they therefore form an equilateral triangle with the point s. At the centre of this equilateral triangle is then taken the centre c of the circle. Then ciis found by drawing the lines a c and b c at inclinations of 30°, or by bisecting the arches a s and b s at m and n, joining these points with b and a. The division arch at the left is also formed on an equilateral triangle d e f, whose apex d does not lie on the upper circle, but es clearly shown in the subordinate Fig. 1234 a remains somewhat distant from it. The point of contact t of the circle and division arch lies farther sidewise on the line e c. To find the points e and t without trials, about c is to be struck a circle with radius c m + e f, whose intersection with the middle line of the jamb mullion g gives the point e.

The detachment of the great circle from the apex of the division arches is seen more clearly in the window of three divisions in Fig. 1240, where even at i the rounds are distant from each other. On the window of two divisions the separation only becomes perceptible when the upper circle is quite small (a b in Fig. 1230). In the present Fig. 1234 it almost entirely disappears, and one can entirely avoid it if according to the scale of the right half of the Fig. the division arch is made more slender, so that the centre g is lower and nearer the exterior. To obtain g a vertical is erected at the middle of the opening that cuts the circle at i, and then is drawn the line c i on

whose extension must lie the point g.

When instead of the circle the window has a trefoil or quatrefoil, then the laying out may proceed in the same manner, when the middle lines are first drawn, but the end is better attained, if one begins with the clear opening of the upper polyfoil, lays off the midth of the moulding outside this and the adds the division arches.

Window with trefoil.

A window with a great trefoil and trefoil division arches below this is shown by Fig. 1235, the sections of the mullions being given by Fig. 1235 a.

The centres of the pointed arches may be at a and b. First are to be struck the concentric arches resulting from widths of the jamb mullions. Accordingly from a and b with the radius a b is made the intersection c, and from c with the radius a d the arch e f, in brief one constructs the circular triangle e f g based on the equilateral triangle, then bisecting the arches e g and f g and drawing through the bisecting points to the apexes of the opposite angles the straight lines a C and b C, the centre of the arches of the trefoil lie on these lines, and indeed according to the desired acuteness of the points h are nearer or farther from C. Then are struck the separate concentric arches formed by the bar section of the trefoil. Beneath this is added a round (left half) or pointed trefoil, (right half), so that at the narrowest places u o or p s the middle flat of the bar has its normal breadth.

Window with quatrefoil.

Fig. 1236 shows a window with a quatrefoil in its upper part, and the size of the quatrefoil leaves wide play, and here is assumed one of moderate dimensions. The section of the bar may have a round in front.

The centres of the pointed arch may be a and b, and the centre of the juatrefoil may be so assumed, that a c = c d, or in other words that a d is inclined at 45°. The radius of the centres of the four foils, which latter lie on the lines g f and e q equidistant frsm d, are to be chosen so that the quatrefoil has a beautiful shape, and at u is preserved at least the width of the jamb bar. According to the models of Fig. 1196 to 1198 is then taken the distance h i as the radius of the lower trefoil arch, and therefore this can be constructed on the line k k

as a middle line in the way that its inner curve touches the external one of the quatrefoil. For this purpose the distance h i is bisected and a vertical l m is drawn through the bisecting point. On the latter is sought the centre for the arch p q to be struck with the radius h r and touching the arch n o, so that this centre is true for the upper arches of the trefoil, while those for the lower ones can be found on the line h k, according to the acuteness of the points.

Fig. 1237 shows the filling of the space with the compound quatrefoil. Here to show a different procedure, the division arches are so constructed, and then increased by the breadths resulting from the cross section. Above is placed the quatrefoil and to this is adapted the enclosing arch of the window.

There is drawn the tangent a b to the outer side of the division arch and inclined at 45°, which cuts the middle line of the division arch at c. Then is laid off about a third of the distance d e on the line a b from c to f, a peppendicular f u is erected at f to a b, which is cut at g by the middle line of the division arch, and thus the points c and g are centres of the outer arches of the compound quatrefoil. If a circular arc is drawn from the latter, which touches the outer arches of the division arches, then are found the extreme points of the quatrefoil, that in like manner are drawn at all angles of the square a b v u. With equal radii are struck the short arcs of the quatrefoil in a skilfully appearing way. Care is only to be taken, that everywhere at least the full width of the flat of the umllion between the quatrefoil and the division arches, where it is not entirely injurious if the moulding concentric with the quatrefoil does not intersect that of the division arch, but extends beside the latter. The same is true in regard to the proportion of the quatrefoil to the pointed arch. The form of the enclosing pointed arch then in Fig.1237 is arranged according to that of the quatrefoil and its centres are found at o and p. But if the pointed arch must be struck according to the equilateral triangle, it would be difficult to avoid, that it would remain separated from the quatrefoil at its apex.

Another construction is shown in Fig. 1238. Here the ground lines of the pointed arch, whose centres a and b and the widths of the mullions are all given. The inner arches are first str-

struck from the points a and b, c b and c a are drawn, perpendiculars are erected at a and b, and make a d = b e = a b. then from d and e with the radius a f are struck the arches g h and g h′, which serve as first points for the quatrefoil composed of separate arches with equal radii. Under these are then placed the division arches.

Window with three trefoils.

Fig. 1239 exhibits the filling of the arched space with three trefoils. The centres op the pointed arch as well as the widths of bars are given. The regularity of the entire form consists in this, that the trefoils are similar to each other, that the apexes of the lower trefoils fall on vertical lines through t those of the division arches, and the three trefoils are in t the regular relation to the equilateral triangle to each other.

Therefore the centres c c′ must either fall on or below the base line of the pointed arch, according to whether its centres lie at d or are placed further inward. Hence there is sought, after the inner lines of the pointed arch are drawn resulting from the width of the mullion, the centre c in the manner that the inner trefoil passes through a, and cuts the middle line e e with a suitable apex. Symmetrical with c lies at the right of e e the centre c, and above both is c″ as the apex of an e equilateral triangle. Likewise is found the other points on t the large triangle c f g. The moulding is then extended around the trefoil and the point h is found, in which the flat or round of the member intersects the middle line e e on the outer limiting arch. Beneath it follow: the trefoil division arches, whose construction can then be according to one of the preceding methods.

According to the measure of acuteness of the angle i and the width of the mullion, as well as the more obtuse shape of the division arch it may be necessary, for the apex of the latter to lie lower than the point h. Then the centres k k are to be sought, so that the internal arches struck from c through h touch the round or the flat. Then either the first may continue beyond the point of contact toward the apex, or beyond it join the arch of the trefoil, so that a recurved point results for the division arch. Such ogee arches are already found in the traceries of Early Gothic; thus on the windows of the church at Haina. In the Fig. drawn the upper trefoil lies below the

corresponding jamb moulding of the window arch, but instead a also the entire tracery could be moved somewhat higher, so that here could be found a junction just as at the point a.

Allied combinations result in windows with three divisions. An arrangement of a window with three divisions similar to Fig. 1239 is found in a tolerably original condition on the c choir of the church at Wetter. Fig. 1169.

Window of three divisions with circle filling.

When a window of three divisions receives a great tracery circle, the middle division arch is placed lower than the two at the sides. Fig. 1240. To change this proportion there may be inserted between the circle, the pointed arch and the division arch an intermediate figure touching them, as in Fig. 1252.

The insertion of 5 pointed arches in the circle is effected in the following manner in Fig. 1240. A regular star with five points is drawn in the circle and the circle a a is described about C with the side of the inscribed polygon of 10 sides. T The intersectionsof this circle with the star at d d form the centres of the curves of the cusps.

A characteristic design results when the space in the arch is filled by a ground form based on the triple division, thus about according to Fig. 1235, where the middle division arch may have its apex below the opening of the trefoil as on a window of the sacristy of S. Elisabeth at Marburg, which is represented in the Gothic Musterbuch, part I, plate 6.

Window of three divisions with trefoil and trefoil arches.

The filling of the space by a compound trefoil is found in the cloister of the monastery of Haina (Fig. 1241). The centres of the pointed arch lie at a and b. First is struck the arches resulting from the width of the bar, then from a and b with the radius a b is made the intersection e, and from this is drawn with the radius a e the arch d e. In the curved triangle d e s is then inserted the tracery figure, and below it are placed the three trefoil arches of equal width with the middle one somewhat higher than the sides.

A very frequently occurring mode of filling the space is the trefoil shown in Fig. 1242. It is already found in the works of Early Gothic, as in the choir of S. Severi's church in Erfurt, but also reappears in the following period again frequently during the entire 14 th century, and is recommended by its

extreme flexibility.

In this Fig. the centres of the pointed arch lie at a and b. Then draw the arches formed by the middle lines of the outer flats as b f and c g, and there results from their intersection the centre C. Then draw the sides of the triangle located at a b c, here only given in the left half, thus f g, f i and then h i, there results by the point of intersection k of the last line with f b the radius for the circle struck from the centre C. The three tracery projections from the middle circle make a very different impression, according as they are made slender or broad. Here they are so formed, that the little trefoils in the remaining spandrels may have their centres placed at the dividing point f.

The mullion member lying at the basis of the entire form is that shown in Fig. 1229. The two trefoils filling the angles between the trefoil arches are only formed by the inner parts of this member.

The flexibility of the trefoil form shown in Fig. 1242 makes it particularly suitable for filling such spaces, that depart from the ground form of the equilateral triangle, so far as a diversity in the upper foil from the two lower ones does no injury at all to the effect. This difference may either lie in the length of the foils, as if c C were greater than a C, or in their direction if the point C is in the actual centre of the triangle, but is to be moved up or down according to the proportions of the space to be filled.

The origin of the entire trefoil form is to be derived from the wheel window, so far as it results naturally from a hexapartite wheen window by the omission of each alternate one of the arches enclosing a space.

Simple wheel window of the earlier Gothic.

The name of wheel window is to be limited in the strictest sense to those circular panels, which are substantially formed by radial mullions placed to correspond to the spokes of a wheel. These radial mullions stand with bases or without them on the circumference of an inner circle. The surface of the latter can be either unbroken according to its size, and then bear e either a relief or ornamental design, or it may be perforated and with a greater radius be beset inside by suspended arches. (Fig. 1246). In the simplest case the mullions have their cap-

abutting directly against the outer circle, or they are connected by arches of various forms, which either rest on the capitals or in lack of these spring directly from the mullions (Fig. 1243). The blind tracery without glass represented in Fig. 1243 a from the still Romanesque church at Bellerbeck (Hase, Baudenkmäler Niedersachsens) shows the next development of a simple wheel window with columns radiating from the centre, that are connected by round arches and enclosed by a great circle. A d different form results if the columns with their bases stand directly on the outer circle as shown by Fig. 1270. The moulding of the mullions is the same as for all other windows (Figs. 1226 to 1229). Figs. 1243 to 1246 exhibit different similar wheel windows.

Fig. 1243 is based on the octopartite division of the circle. The mullions extend in uniform size (as in a,, wheel windows) from the middle circle to the outside and there branch into t trefoil arches, that are drawn pointed at the left and round at the right. The centres h and g of the latter lie at the middle of the bisecting lines a f and c g of an equilateral triangle.

For a greater diameter of the wheel the number of the mullions must be increased, i.e., instead of a division into 6 or 8 parts, that into 10 or 12 must be taken as a basis. Thereby the proportion of the length of the separate divisions or mullions will dominate, and it is preferable either to shorten t the mullions near the circumference or to arrange a transverse connection. Different ways for attaining the purpose first named are shown by Fig. 1244 in outline in its different divisions.

A frequently occurring wheel window is shown in Fig. 1246. Its construction is as follows.

After the division of the circle is made and the lines a b and c d limiting the breadth of the mullion are drawn parallel to the radial lines of the division of the circle, then is drawn the middle line e f of such a panel and in a side Fig. 1246 a a line g h parallel to the latter. On this line as axis is constructed the trefoil at anyddesired size and the tangent k i is drawn parallel to a b. Now are drawn the lines n m, m c, c z in the side Fig. and then in the principal Fig., beginning at o the parallels o k, k q, q r, so that the centre of the trefoil is found in the main Fig. Below the point t of the trefoil

is then placed the trefoil arch, and indeed in this case, when t u is drawn at 30° with the line f b and from t is struck an arch with the radius t u, whose intersection v with the middle line is the centre of the lower arch touching a b and c d. With the same radius t u are drawn the upper segments of arches.

In the same manner could also occur the upper filling of the space a c by a quatrefoil, cinquefoil, etc.

This construction with a simpler division of the circle, as applied to one in 4 or 6 parts, permits the trefoil to become so large and its lower arches approach so nearly at the centre, that the radial mullions may possibly be omitted, as shown by the line x y in Fig. 1246 a, which corresponds to the radius in the division in 4 parts, the circle is then exclusively filled by the four trefoils, and the entire form passes from the wheel window more into the rose window. This is then a more complex form, where two rows of trefoils or quatrefoils are inserted in the circle, the outer one consisting of about 8 or 12 and the inner of 4 or 6, or where different figures are combined in the same way with each other as with quatrefoils in the outer row and as many trefoils in the inner one, or with trefoils in the outer and half as many quatrefoils in the inner one. Further variations are also given by Fig. 1244, if there the single arches connecting the mullions are changed to trefoils or other geometrical figures.

The combination mentioned above which the mullions of wheel windows may receive in order to reduce their length, can either be made in the manner, that the mullions extend through and the arches are turned between them, or that two systems of cullions arecombined. In the last case either the number of separate divisions can be the same in both systems, and the mullions of the outer system stand on the crowns of the arches to the inner one, or the number of divisions of the outer system may be double that of the inner one.

A magnificent example of this kind is shown by Fig. 1245 taken from the cathedral of Minden. This wheel window is there not independent, but it fills the space of the pointed window arch in a very peculiar and perhaps unique arrangement. Fig. 1245 a.

Difference between the tracery of early and middle periods.

The tracery of the middle period differs from that of the e arly period in this, that the latter consists of polyfoils

within each other or of simple ground forms, that only seldom have cusps, while in the middle period the polyfoils almost entirely disappear and the tracery is composed of geometrical ground forms, straight lines and arched, but which are nearly always beset by cusps. In the predominance of arched forms has been thought to be recognized a more structural character, and therefore the Early Gothic tracery is regarded as still undeveloped. It would be so if the curved sides of the different figures were actually arched, i.e., consisted of many separate pieces, in which case the jointeng would be made more difficult by the polyfoils. But in reality the origin of the tracery forms is not from arched construction, but is derived from the perforation of a stone slab, as clearly shown in the tracery given in Fig. 1169 from the church at Wetter. But accordingly the curved shape of the bars is nowise compulsory, but it can be replaced by any other straight or freely developed form. Therefore if a trecery consisted of one slab, then the freedom concerning the separate openings would only be limited, that the bars enclosing them should have the necessary size and connections. But if it consists of two or more slabs, care must be taken to have a suitable location for the joints between t them, i.e., that the joints must be placed so that each separate part rests on that or them beneath it, or extends between them like the separate stone in an arch. But these joints must necessarily cut the bars at right angles, thus being vertical for horizontal and radial for curved bars. But such direction of the joints is to be obtained without difficulty even in the least dimensions of the pieces in Early Gothic tracery, as they are represented in Figs. 1236 and 1239, shown by the joints marked s. On the contrary a comparison with Fig. 1247, which is a transformation of the scheme of Fig. 1239 and represents the style of the middle period, shows that the location of the joints is made far more difficult by the peculiarities of this style, by the growth of the curwes of the cusps out of the ground forms.

Accordingly there is a special consistency in the forms of Early Gothic tracery, in so far as they do not affect the pure arched form, where this has no structural importance, but on the contrary combine these and thus exhibit polyfoiled forms, which could not be employed with actually turned arches, but

are here the more in place. But further advantages result, as already noted above, for the treatment of the interspaces and finally for filling the window with glass paintings.

Simple tracery of the middle period.

The characteristics distinguishing the middle from the early tracery have been already explained, that this composed of polyfoils was entirely supplanted, and it is to be particularly deduced from this, that it afforded certain advantages for the treatment of windows in several divisions. Let Fig. 1231 be the scheme of a windou of four divisions, in which each of the two dividing arches are to be filled in the same way as the great pointed arch bn two smaller ones and a circle placed between them. Accordingly the upper circle b g will have a predominant sizel and hence in some cases a division of it would be desirable, which as already stated, may then be effected in different ways. On the contrary, if this circle were a trefoil (as in Fig. 1235) or a quatrefoil (as in Fig. 1236), then would a further division by possible only with difficulty, an so far as just these forms indicate the limits of divisibility.

Window of two divisions.

Each Early Gothic form is accordingly transformed easily into one belonging to the middle style, if instead of the polyfoil the corresponding ground forms of cusps are taken. Thus Fig. 1247, whose construction results from that already treated, accordingly corresponds to Fig. 1239, and thus the trefoil in Fig. 1235 would be transformed into the three arches with cusps and the division arches into pointed arches with cusps, and the quatrefoils in Figs. 1236 and 1237 into the four arches with cusps. The Fig. last named is particularly common and recurs in different proportions. Thus the four arches with their upper spandrels may either join the enclosing pointed arch or may be free from it (Fig. 1249).

The construction of the first case is the following. Let a b be the centres of the pointed arch, then erect a perpendicular to it, make a c = a b and strike from c the arch d e with a b as radius and also the arch d f. The four arches depend on the location of the centres a and b for the window arch. The closer a and b approach, the larger will be the four arches and the more are the division arches forced down below the ground line a b. The centres a b g c must always lie on the angles of a square,

since otherwise the four arches would be distorted; in no case must it be reduced in width, so that e f is greater than d m, for rather should the converse occur. The construction of Fig. 1249 is then made in different ways, according to the proportion of the radii of the pointed arch and of the division arches to their spans. They differ from Fig. 1248 in this, that the four arches are independent from the enclosing pointed arch.

In like manner are employed the three arches for filling the space, and when this lower spandrel is omitted, it leads to Fig. 1250, in which the space a b c d shows a form allied to the fish bladder.

Simpler but less successful tracery results if the division arches are struck with the radius of the great pointed arch, so that the spandrel falls in the latter in like manner as the arc a b in the window with three divisions in Fig. 1260.

All forms heretofore shown gain in richness, if in each division arch is inserted a trefoil with cusps, Fig. 1251, beneath which is then a second pointed arch with cusps in the manner, that its vertex enters the opening, that is formed in the lower spandrel of the trefoil by the course of the entire tracery m moulding concentric with the curves of the cusps, like a b c d e in Fig. 1247.

Window with three divisions.

Far more varied become the tracery forms of the window with three divisions. As the final form of the most common treatments of this kind may be taken Fig. 1252, which results from Fig. 1240 by the addition of two to the great pointed arch, circles touching the middle circel and the middle division arch. In Fig. 1252 the middle division arch is placed on the ground line a b of the great pointed arch, when the radius of the middle circle is easily found.

The entire form is extremely flexible, and therefore is just as well suited to every proportion of the great pointed arch, since the character of the whole can be modified by the different proportions of the circles to each other and according to the heights of the division arches. This diversity may be increased according to the number of the cusps inserted in each circle. Further the four arches may replace the upper circle, while beside them are either turned other circles or a trefoil as in Fig. 1253.

A simpler form is shown in Fig. 1254, whose condition results of itself, and all proportions of the arched space can be adapted. This is found especially common in brick construction, w where then in the simpler works the spandrel a b c remaining between the division arches is often but partly opened or is also left entirely blind.

In all these cases the division arches are in intimate connection together as with the filling of the space. But an entirely separate group is formed by those traceries in which the space forms an independent shape, beneath which the division arches abut with their apexes. In a sense Fig. 1255 already f forms a transition to the traceries of the last kind, and would be entirely counted with them, if the lower arch a b were entirely closed.

Very decidedly is the space of the arch isolated in Fig. 1255 a, which exhibits the skeleton of a window of four divisions from the cathedral of Erfurt, which otherwise is to be with the compound traceries (see above).

Likewise belongs here the form of Fig. 1242 very frequently occurring in the traceries of the middle period, and especially when the trefoil is also closed beneath by an arch.

Sometimes the form of the tracery on the old works also has required the ground form of the arch, so that its centres are placed beneath the ground line, when thereby is aided a complete development of the tracery. Such an example is found on t the church of S. Jacob in Erfurt (Gothisches Musterbuch, I). But already in the Early Gothic period were allowed such freedoms as are shown in the east window of the church at Haina, Fig. 1265, dating from the first half of the 13 th century.

Tracery of the Late Gothic style.

As we have already stated concerning the fish bladder, generally is expressed the character of the Late time in the dissolution of the geometric isolation peculiar to the preceding periods, thus making possible a freedom and diversity of forms far excelling the latter.

Fish bladders.

The forms of the Early and Late periods often still extend into the later, as then Fig. 1230 also occurs here as a scheme, so that only the filling of the space by the fish bladder is effected (according to Figs. 1213 to 1218). But more decided

are employed the latter, if with the omission of the circle t they fill the entire space as shown in Figs. 1256 to 1259.

In Fig. 1257 the centres of the pointed arch lie at a and b, so that b c = $\frac{c\ d}{4}$. The same proportinon is then also a basis for the division arches, so that also c e = $\frac{c\ f}{4}$. The perpendicular erected at b cuts the arch c g at h. With the radius b f is then struck the arch k h and the arch h l joining the division arch, so that the skeleton of the fish bladder is constructed and at the same time the ogee curve h l replaces the division arch. After then the ogee h m is found in the same manner, the concentric arch resulting from the plan of the mullion can be struck and the cusp be inserted.

A frequently repeated flexible motive is shown in Fig1256. This comes substantially from the filling of the space remaining over the semicircular division arches by two circles about the centre a, which are tangent to the middle line of the division arch and join above the arch e c. When no break occurs, the transition point e must lie on a line with the centres a and k.

The same scheme could also be employed for a window of three divisions as shown in richer form by Fig. 1259.

In it a andb are the centres of the pointed arch. On this g ground line are struck the semicircles a l and t b, and also the circle about c tangent to the latter, the great pointed a arch and the middle line, and further with the radius of the latter the arch c d forming the enclosing pointed arch as well as the arch c e forming the first semicircle. Then draw the line c f at an angle of 45°, and from this intersection with the circle strike the arch g h, which goes through the centre c and joins the pointed arch, as well as from a point k to be found, strike the arch i f tangent to the circle, thus is found the skeleton, and the further execution has no further difficulty according to what has been stated.

To the german forms of the fish bladder correspond those of the French flamboyant style, of which we give an example in Fig. 1258 taken from the central tower of the church of S. Maclou in Rouen. The difference between the two kinds is to be sought chiefly in this, that in the French tracery the fish bladder moves more in one direction, and thus comes nearer the form of flames, while in the german this movement occurs from

the middle outwardin any desired direction, and so more varied motives certainly became possible. In contrast to both continental forms are the divisions of tracery corresponding to fishen bladders or flames in the English perpendicular style, that represent entirely similar diminutives of the spaces enclosed by the mullions and division arches, they extend always in the same direction as those, and so fill the space of the arch in a tolerably uniform way, but produce a rich impression.

Intersections.

We have already stated above, that after the ogee curves it is particularly the intersections which characterize the tracery of the Late Gothic. Though it often occurs in the second half of the 15 th century, that the division arches intersect, while the mullions are connected by a semicircle with the omission of one lying between them, from whose intersection results then t the pointed division arch (Fig. 1261). Another filling of the space may occur by a circle, quatrefoil, etc., with fish bladders next them or solely by the fish bladder in that given in Fig. 1261, an example taken from S. Martin's church in Cassel appears a special consistency, so far as the depressed pointed arch filling the space is formed by two intersecting ogee bars and only in the fish bladders formed at the sides is a cusp inserted in the middle. certainly the scheme given in Fig. 1260 belongs here, to which reference was made already on p. 523, w while here the effect of the intersection of the part c b of t the arch with the great pointed arch is far more tasteful, than that of the semicircles in Fig. 1261 with each other, even if here a certain dryness is also undeniable.

4. Tracery of compound mullion and wheel windows.

Plan of compound mullion windows.

Connection of large and small mullions.

Already in the earliest Gothic, beside the simple tracery windows occur compound ones, which are then formed so that in the parts of a simple large system of tracery are always found a smaller secondary system, or an inverted system of the second order, as indicated in Fig. 1262 by the heavy and thin lines,. The mullions and bars of the inserted second system have a correspondingly more ornate cross section, and they are termed "y "young" mullions in contrast to the "old" or principal mullions. The small mullions are partly isolated (a aud b in Fig. 1262)

ard are partly attached to the principal mullions or jambs (c d e in Fig. 1262). The cross sections of the principal mullions must also be so arranged, that the smaller develop from them as if they were born from them.

Already in the simple tracery beset by cusps, as we have further seen above, the cross sections of the cusps were expressed in the mullions, and similarly but even far more expressed must be the cross sections of the small mullions be contained in those of the larger ones. If in a window with large and small mullions occur cusps at the same time, then the principal mullions will even contain three different profiles and the small ones will have two. In Fig. 1263 accordingly a d g h will represent the larger and b d f i be the smaller mullions, c d e x representing the cusps.

Nowise is the possibility excluded of moulding the mullions relatively richer, for example for a simple tracery with cusps employing the entire frofile in Fig. 1263, thereby giving the cusps the richer moulding b d f i, and on the other hand simplifications of the cross section are also possible.

One can further establish the principles mostly followed in the early time, that only those parts make the compound plan necessary, in which the elevation is actually compound, also t that the plan of the bars according to the spaces with cusps could or must be different from those employed for spaces without cusps or for division arches, as we have already explained in regard to the Marburg window. For such an apparently complicated but naturally a simpler arrangement, the magnificent windows in the transepts and choir of the monastery church at Haina (Figs. 1264, 1265) present the most beautiful examples.

For the former Fig. 1264 a shows the plan of the half of the mullions and bars next the interior. Therein a b c d is the half plan of the large mullion, which includes that of the small mullion b c d. The division arch without cusps has the same plan as the small mullion, and it also continues in the circle above it, only that on the inside are added cusps, whose plan is indicated by c f in Fig. 1264 a. To strengthen or fill the moulding projects before the junction of the cusp in the lower circle w with the part denoted by g, while this is wanting in the great circle, so that the cross section through the great circle on a f is a b c e f in Fig. 1264, and on b f through the small

circle is b g e f in Fig. 1264 a. Since now in the lower divisions the plan becomes more complex, it is again simplified there, where the divisions in the elevation become greater, as in the spaces between the great pointed arch, the upper circle anf the arches enclosing the groups, here taking the form a b i k, so that between the elevation and plan occur the most intimate and alternate relations, and in all down to the smallest part, the finest distinctions are emphasized by the spirit ordering the whole. But this enhanced consistency did not allow the internal tracery mouldings to be employed externally, where on the one hand beside the larger forms of all parts the finer mouldings would have been without effect, but on the other hand just on the north side would have presented too many starting points for the effect of weather.

In Fig. 1264 b is shown the external mouldings in such manner, that a b c d the members of the large mullions are continued on the great pointed arches, as well as on the exterior of the division arches and the bars enclosing the upper circle, e b c d is the moulding of the small mullion here without capital, which continues in the same form on the inside of the great division arches as well as on the exterior of the lower circle, while t the internal side of the latter with its cusps is formed according to f g h c d, so that g h c d becomes the plan of the cusp. On the contrary, richer is the form of plan of the inner side of the moulding on the upper circle according to a e i k l m n c d, so that here k l m c d becomes the plan of the cusp. A similar distinction of the outer from the inner mouldings of the tracery is then also found on other windows of the same church.

The capitals in Fig. 1264 only serve to indicate the beginnings of the arches, and therefore are also found in their actual main lines. In the east window of the same church given in Fig. 1265, they fulfil the same purpose of adjusting the simple plan of the mullion to the more richly formed plan of the division arches. While in Fig. 1265 a, a b c d e is the plan of the large mullion as c d e represents that of the small one, for t the reasons given above the division arches receive an addition by the member f, which as shown in Fig. 1265 b in perspective, is set on the capital at a a in Fig. 1265 and also extends around inside all spaces beset by cusps. The cusps here have a form of section still recalling the forms of the transition style,

while they lack all moulding and simply project as fillets, thus also expressed by d h i in Fig. 1265 a.

Simplified pan of mullions.

As already noted on p. 507 above, there result simple plans of mullions, as soon as the development of the cusps shown in Fig. 1183 is allowed. Accordingly the plan shown in Fig. 1267 a was sufficient for a compound window, if the cusps received the plan indicated by hatching in the right half of the Fig., so that also the hatched part in the left half becomes the plan of the small mullions and the entire Fig. that of the large ones, as it is found on the west window of the church at Haina given in Fig. 1267. But this omission is even increased and then leads to further simplification of the plan, and finally to Fig. 1267 b, in which then m f g i k gives the large mullion, that is only distinguished by an increased depth from the equally thick small one m e c i k, as also w i k further gives the plan of the cusp.

Likewise as on the large mullions there is attached to the jamb mullions half the plan of the small one. Yet are also found many varying conditions, especially in the works of Early Gothic, to which that stiffness is still foreign.

Doubled middle mullion.

Thus in the windows in 4 divisions of the north side of Strasburg minster the middle mullion consists of a doubling of the jamb mullion, so that the small one in Fig. 1267 c are shown b c d the small mullion, b c e the jamb mullion and b c e f is half the middle one, that accordingly consists of two little columns connected by a hollow. On the contrary on the older parts of the cathedral at Wetzlar the jamb mullions are entirely lacking and the division arches grow directly out of the jambs lying in the direction of the thickness of the wall, in which must therefore be cut the groove to receive the glass panels. This arrangement still recalls the starting of the arches of so many Romanesque cloisters, where the growth of the arches is already clearly expressed, but at the same time shows in principle a striking agreement with the arrangement mentioned on p. 507 of the tracery of the Late Gothic castle chapel at Altenburg.

Development of the elevation of compound tracery.

On the laying out or drawing the compound tracery, it may only be stated, that it is just as complete as in the simple tracery

(See above). One passes out from the middle line of the mullion or bar and covers this by the profile, whereby the large and jamb mullions have several parallel lines for the large and small members (c, d, e, in Fig. 1262).

Window in 4 divisions.

The simplest arrangement of the window with 4 divisions is t that based in the scheme in Fig. 1262, of which Figs. 1264, 1265 give two specimens, which date from the same period but are far apart in their effect by the difference in treatment. This diversity is increased to infinity by varying proportions of different parts and a varied arrangement of the other filling, and according to what has been previously stated concerning simple tracery and filling circles, it will not be difficult to find new combinations of this kind.

Windows in 4 divisions with three groups.

However men already began about the middle of the 14 th century to seek variations , and first to make these possible by transferring the peculiarities of the window in 3 divisions to that with 4, forming three groups, the middle one consisting of two spaces, at each side of which remained one space, as the c choir of Erfurt cathedral shows in a rich series of examples. This arrangement is connected with the fillings in the spaces shown in Figs. 1240 to 1242, 1252 to 1254,but always injures in a certain lack of clarity and purpose that simple arrangement characterizing the nature of the matter as opposed ho Figs. 1264 and 1265, but on the contrary this inequality of the divisions forms the natural arrangement for tracery in an unequal number of spaces.

Windows in 5 and 7 divisions.

Hence tracery in 5 divisions can consist of three groups, namely of two double divisions separated by a single middle space, and one in 7 parts may likewise consist of three groups, indeed of two triple divisions separated by one single space, or of a triple division in the middle and two double ones at the sides, whereby the filling of the space is always one allied to the triple division.

The single space between the groups composed of two or three divisions is then enclosed at both sides by large mullions, which remain as division arches above, but sometimes are without the moulding characterizing the large mullions. But thereby also

the division arches will be ineffective, and the filling of the space by the latter is no longer sufficient, and makes the effect have a certain heaviness. Generally a tracery in 4 parts arranged in the manner mentioned, where including the jamb mullions are found four large and but one small mullion, lacks but one more step to the Late Gothic, being without all main and lesser subdivisions, thus being a window consisting of entirely similar spaces and mullions.

Window in 6 divisions.

Just as here the characteristics of the arrangement of the w window of three divisions is combined in a capricious way with that in two divisions, this combination becomes natural for tracery in 6 parts. That either consists of two groups of three d divisions each, or three groups of two divisions in each, so that in the first case the main arrangement of the whole corresponds to that of the window in two divisions, while in the last case the converse condition exists. The first arrangement is found on the west side of the Cologne cathedral according to t the original design, while the latter is by far that generally prevailing and is found on the west front of S. Elisabeth in Marburg, the collegiate church at Mantes and the church of the monastery of Haina. The two examples last mentioned are represented in Figs. 1266 and 1267.

The extremely rich window at Haina belonging to the first half of the 14 th century is in striking contrast to that represented in Figs. 1264 and 1265 from the same church and belonging to the 13 th century, which illustrate the superiority of the tracery about a century older to that of the extreme richness of that later.

There is found in the drawing of the earlier window in Figs. 1264 and 1265 the clear arrangement and the wise restriction of the ornament of cusps to certain spaces, which thereby fully d dominating the whole, contrasted with the uniform spreading of this ornament over all spaces, which is peculiar to Fig. 1267, so that this condition comes more into the light where the simple treatment of the older window with its surrounding architectural details of rounds, side arches and vault ribs, remains in the most beautiful harmony, and the entire surface of the wall imparts a higher life, while the richer form of the west window is entirely loosed from its surroundings, its effect is restric-

restricted instead of being increased. It is further to be well considered, that such window tracery is not there for itself, but at the same time is to serve as a framework for the inserted glass panels, hence must therefore be paid to the glass painting that covers this filling, to afford for this a not too restricted size and form. All these requirements are satisfied by the tracery in Figs. 1264 and 1265 in a high degree, while the uniform predominating later with cusps inserted everywhere offers restricted spaces, and thus is certainly less on the whole than by its own will. Then the glass-worker toiled to master this hindrance, and in these small and limited spaces to insert even overrrich figure and ornamental representations scarcely to be distinguished from below on acconnt of their small scale, making the disadvantages even greater with all the beauty of the glass painting. This existence for self alone is more peculiar to modern art, and appears generally to be increased with the overrich tracery of the middle period. men began to place an extreme importance on it, as already the epitaph of master Reinhold of Altenberg shows, by whom the great west window was completed in 1898, in which he is called "above all the king of stonework". But that Gothic art required rich tracery in a degree far less than is usually assumed, is proved satisfactorily before all by the simple windows in two divisions of the cathedral of Chartres, whose overpowering effect would only have been lost by richer tracery, since the wonderful glass paintings must have been restricted thereby.

As a true model of a simple and still rich arrangement can be taken the window of the north side aisle of the collegiate church at Mantes given in Fig. 1266, which is probably later than the church, and that must date from about the middle of the 13 th century. The plan of the mullion is represented in the right half of Fig. 1266 a.

The construction is simple and as indicated by the lines. The ground line of the arch is a b, its centre lies in the middle line of the side divisions, thus in the points c. At the point c draw a line at 45° with the ground line, which gives the centre C of the trefoil at its intersection with the middle line of the window. From the point C draw the line C e at an angle of 60° with the middle line, erect a perpendicular at the point f, found by dividing the ground line into three parts, which

cuts the line C c at g and thus gives a centre of the trefoil arch, from which the others can be found in the same way. The possibility of the further very original detailing of the trefoil then depends on the width of the moulding, so far that at h i must remain at least the width of the small mullion.

Window of 8 divisions with 8 systems.

As the arrangement of four divisions comes from that with two, so is developed that of tracery with 8 divisions from that of four, it is merely a multiplication. But there are permitted by the size of the space certain richer treatment. Fig. 1268 shows an example from the north transept of the cathedral of Meaux, that entirely corresponds to the scheme of Fig. 1262, The construction is given in Fig. 1268 a.

Bisect a c at d, which distance results from the division of the ground line into 8 parts, so that d is a centre of the pointed arch, whose ground line is also that of the arch f g h, whose centres lie at f and g.

Then lay off a c from a to e and draw a horizontal through e, which is the ground line of the arch k e, etc.; then draw e l = $\frac{a\ g}{4}$ from e to m and draw through m a horizontal, which gives the ground line of the little division arches. Accordingly the different spaces spanned by circles are easily constructed, the w widths resulting from the plan are laid off and the cusps are inserted. But the plan is shown by Fig. 1268 b. The filling of the upper circle is constructed as follows; a b in Fig. 1268 is half of c d, and the centre of the arch a b d on the line a b is about a quarter of its length toward the inside, thus moved to e and f, whereby by dividing the circle in 6 parts the rest results. We give here only a possible construction of this tracery, which we cannot entirely determine whether it accords fully with the actual one.

The advantages of this tracery have been already emphasized in Figs. 1264 and 1265, and these would be compared with the f far richer west window in 8 divisions of Altenberg in the same manner, like that in Fig. 1267. A varied arrangement of tracery in 8 divisions, which corresponds to that shown in Fig. 1254 f for the window in 3 divisions, as shown by the west window of the church of the Minorites in Cologne. Its eight divisions are arranged in three groups, the middle one including four spaces. While then the two arches of the side groups stand on the ground

line of the pointed arch, the middle one is higher like the middle space in Fig. 1254, and the vertex of the enclosing arch abuts beneath that of the great pointed arch. The peculiarity of the arrangement results from the depressed proportion of the entire window, that is avoided by the higher position of the ground line of the middle arch. It shows at the same time a certain relation to the form of the window of the choir of Erfurt cathedral mentioned on p. 528, but far excels the latter in pure c caprice, as results from the basal proportions.

Windows of 9 or more divisions.

Windows in 9 divisions as in the cathedral of York, can be arranged in three groups of three divisions, thus being referred to the principle of three divisions, while one in 12 divisions is formed by a complication of the system of that in 6 parts.

Uniform mullions of the late time.

Differently from the principles stated are formed the richer combinations of tracery of Late Gothic. In the once adopted forms of ogees of fish bladders had men found the means for directly filling any form of space. Any division into main and s subordinate parts would have hindered the unlimited development of these means and was therefore dropped. Accordingly all mullions receiwed the same form, are connected by round or pointed arches, and the latter cling to the fish bladders with unrestricted variety, that are either arranged in groups without these being enclosed by wider bars or independent from each other, t they alone fill the spaces by their artistic interlacings. If in all these the complete dissolution of the Gothic organism is made perceptible, then must one be surprised by the inventive gift, the skill in arrangement, and the taste in the entire treatment. These are the last rays of the sun setting behind the mountain, for which the artificial light then kindled showed itself as a miserable substatute.

Compound wheel and rose windows.

Mullions placed radially.

The principle of compound tracery is also followed by the great wheel and rose windows. Their simple forms were already explained in Figs. 1243 to 1246. From what was there stated will be easily developed the forms shown in Figs. 1269 to 1271. The predominating magnificence of these windows, attainable by no other means, such as the minster at Strasburg as well as that

shown in Figs. 1269 to 1271. The predominating magnificence of these windows, attainable by no other means, such as the minster at Strasburg as well as that shown by most of the French cathedrals, needs no commentary. It has been attempted in modern times to wish to find these in contradition of the true principle of Gothic, but it appears to us unjustly. To exclude them would be to rob one's self. They either occur independenlty on the French cathedrals or are inserted in a pointed window of ordinary form with a straight sill. The arrangement of the sill, which is also generally found where the pointed arch is wanting and manifests itself in the manner, that the deeply moulded soffit arch enclosing the upper semicircle is continued at each side in the vertical jamb or rests on little columns and stops on the wash of the sill, happily removing the possibility that the water could collect in the mouldings extending on the lower semicircle, and brings the entire treatment into complete harmony with the other lines of the interior and exterior. It is already found in works of very early date, like the collegiate church at Mantes, the cathedral of Rheims, the transepts of the cathedral of Paris, etc. But now since the upper semicircle in the interior is inserted within the pointed arch of the vault, the latter may also be expressed on the exterior, and then produce the arrangement of a rose window in a pointed arch before criticized by Kugler, which still has its full justification as being based on the nature of the construction. On the other hand to us appears that transferred from the west facade of Freiberg cathedral to many later works, less happy in the stronger accenting of the enclosure of the circle within a square, since then the upper side of the square in this place is given by no conditions, and therefore represents an arrangement purely based on caprice. (In Freiberg it is connected with the horizontal roof of the narrow passage before the western cross arch and therefore is well grounded). Then whether such an untrue form can be actually found beautiful may be left to an open decision.

Radial divisions.

On many late wheel windows, like that of the west facade of S. Lorenz in Nuremberg (Fig. 1271), the radial position of the mullions is dropped and is only retained for the divisions formed with parallel sides. The entire scheme consists of two intersecting crosses, each arm composed of two divisions, therefore

being a part inclosed by large mullions. The pointed arches connecting the latter then in one cross have their vertices in the outer circle, and in the other in the angle of the arms of the first cross.

A position intermediate between both arrangements in Figs. 1269 and 1271 is taken by one of the wheel windows of the church of S. Katherine in Oppenheim, where the circle is first enclosed by a quatrefoil, each part of which consists of two large and one small mullion, but all are set radially. But between these four divisions are placed four others, in which only the middle line is radial, and is indicated by a small mullion, which is parallel to the enclosing large mullion. The pointed arch connecting the latter is turned toward the centre, and thus joins the large mullions of the quatrefoil.

Geometrical figures within the circle.

According to what is said on p. 520 on the simple wheel window and on p. 511 on the filling of a circle, it cannot be very difficult for a third kind of rose window to construct the different examples, in which the entire area is enclosed by differently shaped and more strongly profiled bars, and filled by inserted geometrical figures bordered by weaker bars, such as circles, trefoils or quatrefoils, etc., in the different areas. Yet for their effect such rose windows remain subordinate, consisting at least in their main parts of radial mullions and spaces, if already for the technical execution, the differences resulting from the great length of the mullions are to be avoided.

5. Balustrade tracery.

Balustrades with mullions.

Construction of the railing.

On the construction of the parapet, that is further more fully explained on p. 363 above in connection with gutters and drips, there will be here mentioned only, that the tracery balustrades consist of separate slabs 15 to 20 cm thick as a rule. If possible they are made of one piece in height, so that the separate pieces meet at their end joints and at the base by the moulding on which they stand, but are connected together at top by the rail laid on them. Hence the joints in this rail alternate with the joints of the slabs and receive in grooves the tongues wrought on these slabs. Where the required height is hard to obtain, they consist of two pieces separated by a bed joint

as on the church of Friedberg, and therefore must have greater thickness so that iron dowels, by which the bed joints are connected, can be held by the mass of stone enclosing them. The thickness is 22 cm at Friedberg. Instead of the stone tongue t that enters the groovein the rail, the connection is sometimes made there at iron pins, as on the balustrade surrounding the terrace on which rises Erfurt cathedral. From the once assumed thickness of the slabs results then the width of the mullions or bars of the tracery according to the size of the openings required by the scheme adopted.

The cross section of balustrade tracery agrees with those of window tracery, except that the groove in the latter for receiving the glazing is omitted. Therefore results the form of cross section given in Fig. 1272. Frequently is found the diagonal square in the thickness of the slab, also the octagon formed from this as well as the earlier shown simple plan of the mullion.

Mullions and little columns.

The simplest arrangement of a tracery balustrade consists of a row of mullions connected by arches. The feet of these mullions are then connected by a horizontal base left on the slab. To the arches applies what is said of the division arches of window tracery; they may be simple round or pointed arches or with cusps, or may assume any trefoil shape. They become richer if in the spaces remaining between the arches are inserted circles, trefoils, etc., as shown by Fig. 1273.

The advantage of these mullion balustrades lies in the easily understood scheme, in the fact that the small width of the spaces permits a frequent repetition, and thereby produces both a rich and a quiet effect. If such a balustrade stands on a stair, the mullions likewise retain their regular form. Every attempt to depart from it, i.e., to form rampant arches is foreign to the nature of the matter, and the raise corresponding to the r rise of the stairs can be produced only by stilting the arches.

The verticals may also be formed as little columns, when the railing is made in the same slab as the balustrade, whose thickness therefore suffices for the capital and base. In the othes case this projection would be entirely useless, to require the thickness to be dressed off for the entire height of the slab. The latter would be superfluous when the mullions assume the forms given in Fig. 1272 a, thus consisting of two little colu-

little columns connected by a mullion without capital. In such arrangements are very effective means for producing a rich effect, yet this must stand very near the eye, in order to be perceived at the small scale.

Height of balustrade.

The height of the balustrade is necessarily arranged according to human height, so that the top rail may come at the usual height of a parapet, thus from 1 to 1.2 m, yet there are also exceptions from this. Thus the roof balustrades of Cologne cathedral are about the height of the shoulder of a man, and those of the cathedral of Rheims are more than a man's height, so that we can only look through its openings. An inconsistency cannot be found in this, since the ordinary height of a balustrade is fixed by the convenience of leaning on it, but this respect fails in a roof balustrade, that merely forms a wall to protect from falling, which therefore on great works may very well assume the character of an arcade. According to this greater height the thickness is also increased, and the entire balustrade may be subdivided with large and small mullions like windows in several divisions, and like the upper balustrades of the cathedral of Cologne. A similar treatment for smaller dimensions would only be permissible in purely ornamental architecture, particularly on internal structures like altars, tabernacles, etc.

Tracery balustrades proper.

Polyfoils arranged beside each other.

The entire arrangement of mullion balustrades was originally based on a construction differing from the perforation of a stone slab, whereby the columns or mullions were peaces cut separately, that were longitudinally connected above by the arched pieces and below by the sill or directly by the slab on which they stand. (Note). But evidently the perforation of the slab leads rather to a form of tracery consisting of polyfoils, circles, quatrefoils or other ground forms.

Note. Some examples of this kind are found in the Dictionary of Viollet-le-Duc.

Fig. 1274 shows a balustrade composed of trefoils placed beside each other, and Fig. 1275 has one of triangles with inserted cusps.

By changing the position of the forms, by the introduction of the trefoil in Fig. 1274, By insertion of cusps in it, by inclosing

it by a circle, etc., or by connecting the motive indicated with another, and further by the repetition of the scheme in two rows over each other may be produced an infinite variety.

Fig. 1276 shows a balustrade composed of quatrefoils, which is contrasted in Fig. 1277 with a corresponding form of squares set diagonally and beset by cusps. If already the treatment shown in Fig. 1276 is more peculiar to Early Gothic works, it is sometimes found occasionally about the middle and end of the 14 th c century, as for example on the roof balustrade of the church at Friedberg and the Wiesen church in Soest. Peculiar combinations further arise by the alternation of horizontal and diagonal squares as shown by Fig. 1277 a. In both Figs. 127/ aod 1277 a t the skuares are replaced by quatrefoils or square openings with cusps, as on the west facade of Cologne cathedral. Particularly characteristic is the occurrence of the apex of the square or quatrefoil in the opening between the arches of the cusps or of the quatrefoil as in Fig. 1277 a.

A substantial change in the effect of the tracery is obtained if any single figure is enclosed in a square, so that thus in Fig. 1176 the quatrefoil and in Fig. 1176 the lozenge are separated from each other by vertical mullions. These latter may then have a greater width, so that the end joints of the separate slabs pass through their middles, while then usually occur in the diagonals of the separate figures. Here as in the window tracery it is first of all essential for the joints to cut the bars as nearly as possible at right angles, thus that all acute angles, all projections of certain weak points in the joints be avoided, since the latter result if the joints are cut through near the middle of a cusp.

Late balustrades.

From the transformation of the square in Fig. 1277 into a quatrefoil results sometimes occurring in Late Gothic works a continuation of the arches to the upper and lower horizontals as shown by Fig. 1278. Otherwise is characteristic for the balustrades of Late Gothic most of all the increased use of the fish bladder motive, and the possibility of the most astonishing combinations thereby produced. These fish bladders are inclosed in either circles or other ground forms, or they fill with their varied interlacings the entire surface. In spite of the lack of easy understanding peculiar to these forms, their effect is still

generally extremely magnificent.

But an increased interest is attached to them, since they represent the transition of the Late Gothic foliage friexe. Thus with less transformation could be made a foliage frieze from a Late Gothic tracery frieze, or the converse; hence both are usually found connected together. Thus the greatest diversity of the separate forms in each species leads quite directly to the transition of the separate species into each other, and hence variety in details to uniformity in the whole. Perhaps accordingly one would not fail, if in the design of new forms of any kind, in any material, when everything possible is avoided, that could easily be transformed into another material, another species, since it is the generally hardest problem to conceive the character of every part as sharply as possible, and to represent it as clearly as possible.

Late Gothic tracery balustrades are found in great numbers in all provinces of Germany (Kallenbach's Chronologie). As for the best examples are to be considered indeed those in which a are still indicated the enclosing forms, even if broken and not fully developed. A very beautiful balustrade of this kind is found on the former organ gallery of S. Severi in Erfurt on the east wall of the north transept (Fig. 1279).

As a single example of this kind may this construction find its place here. The entire scheme is based on a network of equilateral triangles c x k, k b s, etc. From the points a, b, c are struck the circular arcs d g v e, f i n g, etc., and from the points h i k, the arches l m, n o, p q, etc.; thus draw in all triangles the bisecting lines r s, r i, a k, a t, etc., place the compasses on u and open them to the arch l m and carry the circular arc to v. Then from v with the same radius make the intersection w and strike from w the arch v u, thus by repetition of the procedure is constructed the entire skeleton, and it is only necessary to cover it with the width resulting from the cross section and to insert the cusps to complete the Fig. The junction with the vertical side of the enclosing rectangle is made as follows. With the radius of the great circle, thus with q k, strike from a point on the produced middle line the arches belonging to the sides x c and y c of the triangle, and place in them the ogees z z.

Blind balustrades.

Blind tracery balustrades are formed in the same manner and permit a lesser thickness of the bars and accordingly a more c complex plan of the scheme. Concerning the plan of the mullions (if the blind balustrade like Fig. 1263 is to be formed) it is to be stated, that the effect in the mass is more pleasing when it boldly projects from the ground, as if with chamfers or coves that intersect behind the mullions, or when the space bordered by the mullions is formed as a flat segment.

We shall again collect briefly all to be taken into consideration in the design of a balustrade.

Requirements in a balustrade.

1. The entire height including the rail is determined according to the purpose of the balustrade, the place where it is located, and within certain limits (as in Cologne and Rheims) also according to the dimensions of the building.

2. The thickness of the slab is generally determined according to its height and as a rule amounts to 1/5 to 1/7 of the height.

3. The form of the tracery and the development of the scheme depends on the height of the position, on the unbroken length, and on the dimensions of the adjacent parts. Therefore the scheme must be entirely recognizable from below, be so often repeated that it becomes easily understood, and differs somewhat from the dimensions of the adjacent forms of tracery in the intersecting gables or pinnacles by either greater or smaller dimensions. The length of the balustrade here comes so far in consideration, that the termination of the tracery at the end may be clever.

4. The ground of the bars of the perforated tracery is arranged according to the thickness of the slab, the scheme of the tracery and the nature of the materials. The width of the bars may be to the thickness as 1 : 1 or 1 : 2. The choice of cross section depends on the greater or lesser simplicity of the scheme. The width of the bars is best in the same proportion to the width of the larger openings as that of the thickness of the slab to their height. The nature of the material is so far an influence, as a too hard as little as a too easily weathered stone permits a small size of the mullions and bars.

6. Gable tracery.

Tracery of window gables.

Gable tracery is chiefly used in the so-called window gables, and there fills the irregular spaces remaining between them and

the arches of the doors and windows. If the ashlars composing the masonry are bonded in the wall, then the tracery is blind, i.e., perforated; but if the window gable stands free before t the face of the wall or balustrade, the tracery is perforated and bears the coping, and its scheme as well as the jointing of the separate pieces must be formed according to this structural purpose.

The nature of the space to be filled leads first to the scheme of triple division, and thus to the trefoil (Fig. 1280). If the triangle on which the latter is based stands with its vertex upward, then if the direction of the apex of the gable varies from the sides of the equilateral triangle, either the trefoil is s separated from the gable as in Fig. 1280, or an irregular form must be assumed. Instead of the trefoil may the filling consist of a kuatrefoil placed horizontally or diagonally.

With greater dimensions the height of the vertex of the gable above the trefoil or quatrefoil may be too great to do without further support. The same condition also then occurs in regard to the two lower spaces a b c, it is nearest to further divide the space remaining by other inserted forms of tracery. Such a skeleton arrangement is taken from the southwest portal of the cathedral of Rheims as shown in Fig. 1281, that indeed can give no idea of the high magnificence of the French original, how the great spaces are filled by rosettes, and before the middle one stands the statue of the interceding Maria, toward whom the saints in the adjacent gable turn. A similar arrangement is found in the west portal of the church in Cologne.

A different filling results from vertical mullions connected by arches, their feet standing on the outer line of the arch, as on the high altar of the church of S. Elisabeth in Marburg. The skeleton of such an arrangement is shown in Fig. 1282.

A very suitable form of tracery for these gable spaces is given by the trefoil contained in Fig. 1242. By its peculiar flexibility it is particularly adapted to be added to all forms of these spaces varying from the shape of the equilateral triangle. By the use of large and small mullions, the last of which divide again each part of the trefoil in two or more spaces, by the insertion of other figures in the spandrels remaining between the different parts, the effect may be enhanced to the highest degree, as before all is shown by the cathedral of Cologne.

A construction usable generally, on account of the changing proportions of the apex angle, of the gable and of the radii of the pointed arch, is impossible and only an abbreviated method of trial varying in each separate case can be employed, some starting points of which are given in Fig. 1283. Let a b there be the slope of the gable and a c be the outside concentric arch of the window. It is next to find a favorable centre g for the entire trefoil, and it is best chosen so that a circle can be struck from it, which at the same time touches the crown of the arch and the line a b. The three tracery foils projecting from the middle may have wide or narrow proportions; they can je so determined that in the spandrel a c d is sought an inscribed circle with the centre e, and from the point of tangency g is struck the arc i h so that it is tangent to the line a d. With the same radius is struck the other arc i m. In the upper spandrel is assumed the same pointed arch p o q. From k is struck a circle with a radius of half g h, in this is inserted a trefoil, and then is drawn the trefoil arch and the pointed arch m i h or p o q and at the same time the tangent lines p r, r h, etc. Thus is found the skeleton of the trefoil. This can accordingly be covered by the widths resulting and be further executed with the inserted cusps, or in greater dimensions be developed in a richer form. At the end might be inserted between the three divisions either the circle u or other forms and accordingly regarding the entire form as the skeleton of the large mullions. Each of the three divisions may then be divided by small mullions, whose middle lines are represented in v w, x y, and also the circle u be subdivided by inserted figures.

In the original elevation of the west facade of Cologne cathedral the filling of the gable above the upper sound opening of the tower is in a certain sense opposed to what is stated above, while the three great tracery arches of the spandrel are turned toward the centre of the gable area, in which they meet the spandrels, so that each of the three spaces assume the form of a colossal fish bladder. The further division by small mullions and tracery forms still heighten the appearance of the fish bladder.

In the later periods of Gothic art, in which the form of the fish bladded had come into general acceptance, the rectilinear window gable was almost generally supplanted by the ogee arches,

the so-called ass' back, which in the lower part bent close to the arch and therefore left no open space between them for the filling tracery. They are then found to be filled less with tracery than with foliage, figures or symbolical representations.

Tracery in great gables.

Tracery in the great gables of the transepts, of towers and of private houses, is already found in the earlier time, it consists of division mullions connected by tracery, of great roses, trefoils or of smaller geometrical figures, that extend uniformly over the entire surface. Especially peculiar are the gable fillings composed of moulded bricks on many brick structures, which already occur in a very early time (Ratzeburg, Colbatz in Pomerania, and Riga) and finally continue in the Renaissance. Some particularly rick examples of such later gables are afforded by Stargard in Pomerania in its city hall and some private buildings.

DOORWAYS AND PORTALS.

1. Arches and Jambs of Doorways.

Simple members of arches and jambs.

Note. See examples of the Gothic period in Statz and Ungewitter's Gothisches Musterbuch, further in Hartel's Architectural Details of Middle Ages, and Redtenbacher's Beiträge zur Kentniss der Architekturof Middle ages.

Doorways with arch and lintel.

The usual construction of the door leaves in wood prescribes for them a rectangular form or one approaching it, so that covering the doorway closed by leaves , a straight lintel extending between the jambs appears to be nearest. Fig. 1284.

Variations from this rectangular form of doorway are found in the smaller doorways open to to their round, pointed or segmental arches (Fig. 1285), as well as in those portals of the transition style and of the Early Gothic period, whose doorway openings are covered by a trefoil arch (Fig. 1286). Meanwhile the door leaves follow the outline of the ppening just as little as they are usually cut to the form of the corbels supporting the horizontal lintel, but they are rectangular against the internal face of the wall, in a rebate seen at i in Fig. 1284 a, or in a blind recess covered by a segmental arch. See plan in Fig. 1285 a and the back elevation of the doorway, Figs. 1285 and 1286 a.

The clear length of the door lintel can be reduced with great advantage by two corbels projecting from the jambs (Fig. 128.). If the lintel is then loaded by a wall, then further is necessary the arrangement of a so-called relieving arch b. Since for the lintel as well as for the rebate of the door is sufficient a moderate depth of about 30 to 40 cm even for important dimensions, but the wall is more in nearly all cases, it would be useless to carry the rectangular opening and also the lintel through the entire thickness of the wall, this is only necessary for the relieving arch. Thus was already formed a motive peculiar to Romanesque works, whereby the round or later the pointed releiving arch was expressed, and the space beneath it with the lintel and the masonry of the same thickness resting on it, or in smaller dimensions it closed by a slab of the required thickness fitted to the arch, the so-called tympanum. Like the lintel, the latter rested on the corbels projecting from the door jambs,

or on a part of the jamb, or finally on a combination of both arrangements.

Stepped jambs of arches.

The jamb is divided in two parts, the proper door jamb (g in Fig. 1288) that supports the lintel or slab, and the jamb arch (e f in Fig. 1288). The jambs of most Romanesque and many Early Gothic portalr show externally more or less numerous rectangular steps, where is inserted a column in each angle. This column is either as in Fig. 1288 cut in the ashlars of the jamb, or it is made of a separate stone set on end (Fig. 1288 a) and free, the capital and base bonded in the wall. Longer columns with shafts not readily made in one piece, receive at the middle a band fastened in the wall (Fig. 1286). Particularly beautiful is the effect of the little columns, when set farther from the jamb, so that capitals and bases can develop freely as in Figs. 1287 and 1287 a.

The portal arch consists of several courses turned concentrically above each other. Its division may exactly or approximately correspond to that of the jamb, so that the columns in Fig. 1288 continue in the arch as equally or somewhat larger coursed rounds. Even the columns set on end in Fig. 1288 a may be imitated in the arch, where freely projecting rounds a (Fig. 1289) rise from the capitals, which in the transition styli are held by frequent bands b . As in the Fig., the latter take the usual form of rings or bands, or they consist of separate round disks imitating keystones of the arch, such as also occur on the ribs and have already been mentioned there. Likewise is generally a avoided the hook-shaped form of the keystone resulting from the pointed arch, that in the crown is inserted a bonding member in a vertical position, which the halves of the arch adjoin, of w which the north portal of the cathedral at Riga presents a beautiful example in Fig. 1286 (First half of 13 th century). Here the bond extends through the members and bears a corbel at top, which originally received a fegure.

If the round of the diameter of the column is the smallest member, that can be developed above from the column, on the other hand a curved block can be placed on the correspondingly enlarged capital of the column, which fills the entire square a b c d in Fig. 1288 a. While the stepping of the jambs shows the four angles b, d, f, h, the arch members then show only three

more strongly projecting angles a, e, g. Within these limits m moves the dimensions of the members of the arch. The rectangular angles may be broken an animated on both jambs of the arch by chamfers or by richer mouldings.

There is a certain relation of the doorway arches with the more richly treated side arches, and liekwise to the jambs of the doorway follow the motive of the pier.

Continuous splay behind the columns of the jamb.

The arrangement thus far explained is common to the Romanesque and Gothic portals, and it makes no difference in the form of arch, since a no less number of Gothic portals are covered by a round arch, like the main portal of Notre Dame at Dijon, the s south portal of the church at Haina and two side portals on S. Elisabeth's church at Marburg. An actual difference therefore exists only in the details, as well as in the more slender proportions of the columns. But as a decidedly Gothic motive is regarded the rpplacing of the rectangular angles of the jamb between the columns by a continuous splay, but where the arches retain the old stepped form for structural reasons, as we have mentioned in relation to the side arches of Freiberg minster. Fig. 1290 shows the plan of such a jamb with the arches and the capitals of the columns, where the splay adjoins a rectangular reveal a, that can be moulded on the angle. Just as those rectangular angles of the jamb between the columns (Fig. 1288 a) w were usually moulded, so may also the splay be animated by a system of mullions or smaller columns connected by arches, either placed behind or between those in front, and the crowns of whose arches stand below the underside of the capitals of the latter (Figs. 1291, 1291 a). On this rear colonnade the arches may also be omitted, and the solution made on the splay be a horizontal moulding or continuous cove extending from the cavetto from which rise the capitals, or finally be made by a connection of the capitals with each other. We shall see below to what reductions this arrangement leads.

Bonded and free little columns.

The little columns made of entire pieces and set free before the coursed masonry of the jambs, which is the rule in France, is less commonly found in Germany as well as on the piers, and the local position appears to have had no influence thereon. Thus they are found on the Early Gothic south portal of the

church at Haina, while they are avoided on the scarcely later portals of doorways of S. Elisabeth's church at Marburg, only a few hours distant. The same conditions appear on the almost contemporary churches at Volkmarsen and Wolfhagen belonging to the Westphalian architectural group. A diversity of materials did not cause this difference at the places mentioned, nor even the dimensions of the portals, which nearly accord. Meanwhile in the existing cases just from the latter may be derived the determining reason for the choice of one or the other construction, for the arrangement of the free sta ding little columns certainly seems to require certain proportions in dimensions.

If we place little free columns in Fig. 1287 a in connection with those sectangular angles of the jambs with a width of 1 to 1.2 m of the doorway and a height of 2 1/2 to 3 m, the dimensions of the sides a b ara first determined by the usual dimensions of the ashlars, since on the one hand that adoption of the stepped plan is based on the acceptance of the joints b c and b d, on the other the dimension a b is again dependent on the depth of the arch, which again is fixed by the ordinary dimension of the stone, hence as a rule being at least 25 to 30 cm. Accordingly there certainly results for the little jamb columns moderately heavy proportions as shown in Fig. 1287. If one would reduce the dimension a b, then would the joints b c and b d be omitted and two angles must be formed in one ashlar, i.e., in one ashlar must be cut the angle a b a, namely filled to the little columns. But also aside from this, the little columns r require a certain thickness at places exposed to frequent contact in order to be stable, at least 12 to 15 cm. On the contrary would be permitted the cutting of ornamental forms in the mass of the ashlar. In the richer examples of Early Gothic the bonded members are fully developed as little columns. Such an example is presented by the south portal of S. Elisabeth's church at Marburg, where as shown by the plan in Fig. 1290, where in the angles of the jambs are wrought a greater and two smaller ones separated by hollows. There the elevation shows that all 3 little columns begin with their own capital, which however by the great projection of the middle one unite in an abacus forming 3 sides of an octagon, so that by this is obtained the required base for the mouldings of the jamb substantially differing from the section of the arch and jamb.

Separation of arch and jamb.

That separation of the form of the arch from that of the jamb, which is wanting on simple works, on the other hand is frequently found executed on later portals and with an entire harmony of mouldings and the omission of the capitals thereby caused, that the hollows first from the base of the arch, or if this were stilted, from the underside of the lintel, are filled by the most varied plant ornament.

On the separation of the arch from the jamb was generally laid so much stress, that even with entirely similar members the capital was unwillingly omitted, or its place was occupied by a branch laid on, an animal or a shield of arms as a separation. Even the latest Gothic still menerally separates the arch from the jamb.

Foliage and figure ornamentation on arches and jambs.

Foliage on the arch.

Only simply executed works were satisfied by a mere moulding of the arch layers. If men already in Romanesque and especially in the so-called transition style had sought richer decoration of these arches in the most varied ways, Early Gothic art continued in the same course and ornamented the separate layers of the arch with the most charming forms of foliage, indeed all, or so that decorated alternaded with moulded ones. The arrangement of the foliage is about as follows. A great simply cut cavetto or one with little rounds placed on the flat surface is cut in the angle of the ashlars and covered by foliage. This cavetto either passes above the capital back into the rectangular angle in any manner, or it extends to the capital, yet as a rule so that some bold form, a head, an animal, or a bending of the stem of the foliage is on that intermediate surface and thus forms the transition. The foliage itself is suited to the jointing in its separate parts, and the separate leaves, bunches of leaves or plants stand in a line concentric with the arch as in Fig. 1293, or radially and thus across the hollow, or they are placed obliquely, or finally they form a continuous and still more conventional ornament, on the earlier French examples. Usually are also found here this volute shaped bunch of leaves, and indeed in the same positions and thus either projecting from the hollow, or supporting its upper edge from the lower one, generally connected by leaves, about as in Fig. 1294. These volutes sometimes

grow out of the rounds instead of the hollow and even project beyond the face of the arch. It is to be noted, that the sharper separation formed by the volutes, also on the older examples. The arrangement of liner forms of foliage is striven for by the movement of the leaves (Fig. 1293). A very rich example of the connection of volutes with leaves is shown by that south portal at Marburg (Fig. 1290). Also generally the foliage at smaller scale is placed in the hollows separating the round at both sides from the flat surfaces, so that two such bands adorned by leaves are formed beside each other.

Figures in the arch.

In the richest style there also occur here figures instead of foliage, and indeed it has been led to one of the most ingenious motives beculiar exclusively to Gothic architecture, namely to that splendid arrangement of seated or standing figures, separate or arranged in pairs or forming groups, covered by canopies and again seated on those, in this alternation occupying t the entire layer of the arch. The figures on the arch represent the blessed in a serial arrangement as a frame of the sacred scenes on the tympanum, on the inner arch being the angels, on the next the church fathers, etc. The entire arch appears like the vault of heaven peopled by saints and the blessed. The sight of the series of arches diminished in perspective is led from step to step nearer the divine, which finds its own place in the tympanum.

The structural execution is about as follows. In Fig. 1295 a let a b be the moulding of the arch layer, then the part of a polygon inscribed in the right angle d c b gives the plan of t the canopy, just as the separate figures are cut in the highest relief from the same mass d c b; Fig. 1295 gives a view of such a piece of the arch. There each figure is made from one ashlar, so that the radial joint goes between its head and the upper canopy, or it is also found under its feet, which then either goes through the clothing or a piece of the base, or finally a low pedestal is united, again being a joint. Thus the crown of the arch is either formed by two canopies growing together, or the last canopy of each half arch remains a little distant from the crown, whereby the keystone between them either remains void, or is adorned by a separate figure like one standing upright, a. head or by foliage.

On the later works the endeavor to create those figures in greater relief led to replacing those wrought from the ashlars of the arch by free figures, so that only the canopies are regularly wrought from the arch, but between them the hollow is cut smooth and at its back is fixed an iron hook, and later holds the back of the free figure when placed there.

Not entirely with injustice in modern times has the last mode of fixing been blamed. But in an exaggerated way this blame was also extended to the first entirely structural arrangnment, was based on the position opposed to the laws of gravity, as if the same objection could not be made to all slucpture of the kenst- one and further to all covering ornamentation. The soaring position of the figures can here offend the less, since as stated, such usually represent the inhabitants of heaven.

With the construction of the arch of several concentric layers, there results from their unequal length the necessity to increase the number of figures toward the outer layer, so that in the innermost half are 5, in the next 6, in the outside one 7 find the same space.

Figures before the columns of the jambs.

On richer works the jambs as well as the arches are adorned by figures, which by their dimensions usually exceeding life s size are distinguished from the latter, and therefore require a special mode of placing. On the older French works these have their corbels in a way similar to those of the voussoirs, they are wrought from the little columns of the jamb forming monoliths, which easily furnish the required mass for them, since these in the rarest cases can be quarried only in the dimensions required by the diameter of the column. On p. 485 we have already mentioned the same arrengement in regard to the rounds, which is the following. For the shaft of the column (Fig. 1296), which in its round form stands on the bonded base, close above the latter is wrought a corbel, that is described on p. 486, u usually assumes the form of a low canopy, on which stands the figure connected at the back with the column, so that its round form of the column appears above beneath the capital.

According to this earliest and simplest arrangement the figure thus occupies nearly the entire height of the shaft of the column. Over the figure is then required a canopy, which in this equality of height can be arranged in two ways. On the

cathedrals of Paris, Rheims and Chalons the capitals of the columns as shown by Fig. 1298, join a projecting member decorated behind by foliage and cut in the same block, and indeed this joining is either complete, or the capitals project a little b beyond the face a. Thereby they form above the capitals a surface parallel to the rear splay of the jamb a b in Fig. 1299, from which project the canopies, that either in the ground form consist of several abutting or detached polygons as in Fig. 1299, or form a hood parallel to that splan as on the west portal of the cathedral of Rheims. (Fig. 1298). The first arrangement is found in Chalons and on the portal of the north transept at Rheims.

Above the canopy is then placed either directly the arch members or that stilting, so that the original rectangular blocks of the voussoirs, from which the hollows filled by figures are cut, again come to stand over the columns, whereby according to the dimensions of the projection of the capitals a part of the projection of the canopy is either utilized for the base of the figure, or the latter remains behind it. But on certain works there is found no such direct relationof the number of layers of the arch to the jamb columns (Fig. 1299).

The second method of the arrangement of the canopy, that is found on the west portal of Notre Dame at Dijon among others, consists in this, that it is placed one course lower, and thus instead of being one course above the capital, is takin from t the course with the capital. Accordingly the bell of the capital also projects with the little arch of the canopy, and this foliage lies partly beneath according to the general arrangement of the latter (Fig. 1297). The middle of the canopy thus projects before the outer edge of the capital, so that before the arch resting on the latter may still be gade an addition on the canopy.

On the portals of the cathedral of Amiens then disappears this agreement of the heights of the figures and the little columns of the jamb. In the arrangements mentioned, the former stand on a low canopy located above the base, but occupy only a part of the height of the column, above this is then found the canopy likewise connected with the column, which at the same time produces a connection with the jamb, and between the latter and the capital is again a short and free part of the column, so

that directly on the capital again rests the hollow of the arch filled by figures and canopies. On the whole this is the same arrangement, which is mentioned on p 485, and also customary on the vault rounds with figures in the earlier style.

Figures on little columns.

But just as there the proper function of the rounds on later works was thereby changed, so that they are omitted behind the figures, there is found the same arrangement employed on the j jambs of the portal in that way, that the figures stand on short columns, which therefore terminate under them with their capitals, while those upper portions of columns are omitted and the hollows in the arches filled by figures rest directly on the canopies. The entirel arrangement differs froc the preceding in this, that the canopies of figures of the jamb come directly beneath those of the arch and not as in the preceding stand before them. Thus the little jamb columns are entirely omitted a and only like reminiscences of them remain those little short columns supporting the figures, that likewise can be made of detached blocks.

Just as the figures of the arch gain in effect by being placed in hollows, so was next the endeavor to ensure the same advantages to those standing in the jambs, and thus the hollows in the arch under the canopy or impost cap were continued behind the figures to the capitals supporting them, or even to the base, whereby also the canopies of the jamb figures project from the hollows and no longer afford a bearing for the members of the arch. Fig. 1301 shows the plan of such an arrangement.

A very peculiar form of this kind, whereby is preserved at t the same time the picturesque effect of that free standing little column is found on the west portal of Freiberg minster. Here alternates in the arch a layer with a hollow filled by figures with one ornamentally moulded and adorned by foliage in the hollow. Both arrangements are intercepted by little capitals, but otherwise continue in entirely similar fashion down to the base. But in the hollows are 3 little columns c placed in an equilateral triangle in Fig. 1302, whose capitals are taken from the layer of the jamb and end in a common abacus, which rests on a pedestal of the same ground form, whose side surfaces are richly adorned by blind niches and relief figures, and that bear a figure group. Above the latter then begins the usual

filling of the hollow by figures and canopies.

In smaller ones requiring a lesser diameter of the columns disappears the possibility of a free arrangement of the same in entire pieces, and their connection with the coursed masonry of the jamb becomes a necessity, so that the cutting of the hollow down to the base is omitted, and between the latter and the capital receiving the figure a member formed like g h i k in Fig. 1301 takes the place, as on the south portal of S. Maria at Mühlhausen.

Figures on pedestals.

On the west portal of Strasburg minster is then found the arrangement common on richer works from now onward, according to which the supports of the figures abandon the form of the column for those of square or octagonal pedestals to which extend down the hollows filled by figures and canopies in the usual way in jamb and arch, so that thus in the plan of Fig. 1303 a b c represents the plan of the pedestal and a d c is that of the h hollow above it. The pedestals then have at last the height of a man and are decorated on their sides by blind arches usually ornamented by reliefs, spanned by arches crowned by tracery gables in the richest manner.

On those earlier jambs with columns there alternates as a rule a column with figure and a plain one, since then the great dimensions of the figure requires such a change. The same alternation is found on the Freiberg minster, p. 544. But allording to the plan of the jamb at Strasburg this separation of the hollows filled by figures is effected only by the mouldings worked on the same ashlars.

Before we go farther there must be mentioned also certain reductions of that earlier system of treatment of the jamb.

Thus on the west portals of the cathedral of Noyon the little columns of the jamb are omitted, and the figures covered by canopies are placed directly before a plain splay cut behind them. On other works then the figures are also omitted, but on the other hand that splay is divided by blind arches, as such an arrangement in connection with the little columns of the jamb was already mentioned on p 540.

Striking jamb and middle pier.

Side jamb for striking.

The internal projection of the jamb forming the strike of the

door and supporting the tympanum of the arch, according to its separate function, is usually to be distinguished from the other members of the jamb supporting the arch. The simplest case is that of a plain rebate with neither base nor cap, from which r rise only the somewhat projecting corbels for the lintel.

On many older works it receives the form of a plain pier, which is surrounded by the capital and base of the jamb, both of which are cut off flush with the leaf of the door (Fig. 1290).

The angle has a chamfer, a cove or even a richer moulding, in which again predominates a round with a capital. By the capital can either the entire member be returned to the square, a and then the lintel may also remain simply square, or the moulding can tontinue above the capital, break around horizontally and thus accompany the edge of the lintel. (main portal of church of S. Elisabeth at Marburg). It is there preferable that the moulding of this strike of the door be distinguished by greater refinement from that of the jamb.

In every case the corbels are of great service, by which the free length of the lintel in one, the useful width of the opening of the lintel in another is reduced in an entirely unlimiting way, and which can be combined in the most varied ways with each of the forms mentioned, while it may either be connected with those capitals by increasing the projection sidewise as in Fig. 1290, or project from the plain jamb inside the moulding, or finally can be surrounded by that moulding or a part thereof. On richly executed works the fronts of these corbels are decorated by crouching figures.

Middle pier.

But with that unusual width as given by the proportions in g greater works, partly resulting from religious needs, further come a supporting of the middle of the lintel of the doorway a and thus the arrangement of a middle pier, which was constructed either of a single piece or of separate courses. Its forms differ according as it assumes a more independent importance or a repetition of the jamb of the doorway. In the last case which tends more to a treatment with columns, and first departs from the construction in a single block, therefore being possible o only in moderate dimensions, the corbels at both sides must be omitted, if they already exist on the stone jambs. Also sometimes a middle pier built in courses is connected with a freely

projecting column by its capital and base, on which is placed the middle figure rising in the tympanum.

A very peculiar arrangement of the middle figure is found with the omission of the middle pier on the Early Gothic church at Wetzlar. For here the system of the suspended arch is employed on the tympanum, so that the two voussoirs a (Fig. 1300) support the keystone b like a kingpost or struts in wood construction. On the latter are then wrought the abutments against which abut the trefoil armhes c covering the doorway. The figure of the Holy Virgin with the corbel on which it stands is with the suspended keystone are cut in one block. While the spacing by a trefoil arch is also recalled in the transition style, the entire construction is otherwise only a superrefinement peculiar to the Late Gothic.

But in the richer designs of portals with jambs adorned by figures, the middle or principal figure of the entire series is placed before the column b, so that it conceals that for its own height. A connection of it with the middle pier becomes impossible by the great dimensions of the former as well as by the construction in courses. Thus a support for the middle figure becomes necessary, which either can be found by a projecting little column with bonded capital or by increasing the dimensions of the lower portion of the pier. This lower and larger part of the pier thereby becomes a pedestal, whose sides are most r richly decorated by blind arches, indeed frequently in several rows above each other. The canopy belonging to the middle figure is then either bonded with the middle pier, i.e., taken in the uppermost course, or it is already placed in the tympanum, so that the latter rests beside it on the middle pier, then receiving its bearing by corbels increasing the supporting area. Meanwhile also in the first case the finial of the canopy may rise before the tympanum.

The corbels are sometimes replaced by arches turned under the lintel from the middle pier to the jambs, which are usually made very ornamental with cusps, and their spandrels are perforated like tracery. In the latter case they must remain so far from the strike of the door, that they are not struck by the leaf of the door. Also sometimes the lintel is replaced by a segmental arch, or as occurs on certain French works, by a horizontal arch. Usually also and particularly on works in brickwork, the arran-

arrangement of a segmental arch over the entire width beneath the tympanum of the great pointed arch leads to the omission of the middle pier.

Base of the jambs of doorways and portals.

Plain and stepped bases.

Simplest is the form of base for small dooways, whose jambs form the simple continuation of the arch members without capitals or base, and intersect below a projection or a wash. (Fig. 1304). This plain solution occurs little in the Early but much in Late Gothic. The lower part of the jamb thereby becomes a plain splayed surface, that extends in an oblique direction from the external face of the wall to the strike of the door, and its top or lower part is surrounded by the plinth of the building, in case this does not end beside the door.

The portals of the early and middle time mostly had, as we have seen, jambs with little columns, that were completely furnished with capital and base. The base received a little rectangular or polygonal plinth, whereby the jambs had below again a regular stepped form, which rested on the steps or could have separate simplified plinth (see below). On the whole the plinths of the jambs exhibit much similarity to those of piers, as already described on p 214 to 224.

The plinth is then often retained when the capital is omitted and in the late time is formed with such labored and even affected richness in the way illustrated in Figs. 572 to 582, that manifestly forms the greatest decoration of the whole, and therefore came to lie higher, at the height of the eye when possible. A particularly magnificent example of this kind is afforded by the portal of the old university in Erfurt.

Conversely on Early Gothic doors of small dimensions as in Fig. 1290, on which the plinth lies very low, and rounds are sometimes decorated only by capitals.

With the adoption of free columns at the jambs, whether these are placed before a stepped plan or a simple splay, there results for the base of the pier about the form represented in Fig. 558, and everything said of that finds its application here.

The stepped or the compound plan of octagonal bases then generally also stands on a connecting general plinth as lower base, that is broken around the front angle of tne jamb and extends obliquely to the inside, finding its termination at the angle

forming the strike.

Under plinth or pedestal.

This under plinth can be formed by the plinth broken around the jamb; if it meets the steps lower or sidewise already before the beginning of the members of the jamb in any such manner is omitted, then in its place can pe inserted a separate and more strongly accented socle, so that a part like a pedestal exists, whose height can then be increased according to the m general proportions. This heightening is also produced in a continuous plinth of the building by breaking it around.

Each pedestal may on its own part be also furnished with a projecting cap and plinth and thereby obtain a certain independence, as then on the great French portals it is elevated to an integral part of the entire design, so that thereby the arrangements of the columns and the figures arerraised to about the h height of a man above the ground, thereby being ensured from any injury and producing a far grander effect.

But aside from the advantages mentioned above, this arrangement results with a certain necessity from the placing of the figures and monolithic columns as well as from the entire dimension:

For those great portal designs, like the widdows, fill the entire space between the buttresses, while the plan of the jambs extends beyond the external face of the wall to the buttresses, about as in Fig. 932. Its width, height and depth thus stands in a certain proportion to the entire dimensions, indeed are to be explessed in numbers. On the contrary the size of the separate courses of the arch and of the jamb members depends merely on thedimensions of the materials, but the increased height of the portal must lead to too slender proportions of the columns. Assuming now that men would adopt the latter and could even obtain monoliths of the necessary height, yet they could not secure the same height for the figures connected with the columns, since the widths of the jambs did not suffice for the breadth of such colossi. Bust as it would appar unsuitable to take a smaller height for these figures, because the required mass of the block would be cut away under them, and thereby only for merely an ornamental motive would the fourfold mass of stone have been used on the colunms. It would only have remained to make the shafts of the columns in two pieces, and to connect them with the mass of the jamb by a band, hence making the

subdivision of the columns, which still in the entire proportion was to be elevated in a far more expressive way to be a subordinate division of the jamb.

Thus the socle mentioned is omitted on all these jambs of portals, whose little columns are wrought from the bonded ashlar courses, while men busied themselves in other ways to appoximate their effect, and just here might be sought the real reason of the origin of those richly decorated pedestals, which occur as supports of figures on tehe portals of Strasburg, Cologne, Rouen, etc., and whose relation to the jamb pedestals, from we started, are even more clearly expressed by the rich mode of decorative treatment.

Development of the socle.

The further development of these socles is very varied. On t the Liebfrauen church at Treves and certain French cathedrals the oblique surface between the cap and socle is animated by purely ornamental blind arcades, whose panels are decorated partly by patterns and partly by figure reliefs, and which appear in the same relations to the colonnades above in this relation, with the little columns that receive the arches of these arcades either stand before those of the jamb or before the middle of the intervals. This arrangement then sometimes leads to a reproduction of the stepped plan of the jamb between the lower little columns, whereby the splay is only indicated by the blind arches and the socle of the pedestal. On the contrary on the cathedral of Rheims the side surfaces of these socles are covered by carved drapery, that is also continued around the buttresses separating the three western portals, like the ornamentation of the portal jambs by the decorative columns and figures (Fig.1305).

The most common mode of treatment consists in the adoption of a tapestry pattern wrought in very low relief on the surfaces mentioned, in which the ground of the separate panles is generally again filled with figures in the flat. Sometimes (thus on the cathedral of Amiens and at Noyon), these sides are separated in two divisions, either the lower being smooth and the upper having a pattern, or their patterns differ from each other in size and scheme. Fig. 1306 shows the treatment concerned on the cathedral in Amiens.

We cannot omit here the remark, that these tapestry patterns

that are so common in French architecture and animate the plain surfaces in so many places, form a substantial and very advantageous characteristic of them, that unfortunately has remained foreign to Germany in a way, at least in the sense here indicated, which was almost too liberal with the use of more severe architectural forms on any favorite place. In reality these flat patterns form an easily executed means for obtaining great richness, and the effect of those severer forms are heightened by contrast, and accordingly they certainly deserve to be introduced also among us.

On the portal of the calendar at Rouen are found those patterns in a way very similar to that in Amiens, executed in the blind panels of the separate pedestals of the figures, and just like those of the middle pier.

2. Tympanum of the portal.

The inner and proper opening of the doorway can be covered by an arch, as we have seen above, whether trefoil, flat or straight arch; but the rule forms the lintel or the stone slab closing the entire tympanum, that rests on the inner pier of the jamb or its corbels. It stands abruptly beneath the arch alone, rests behind in a surrounding rebate, or is let into the jamb arches like tracery (Figs. 1148 to 1148 c).

Joints in the tympanum.

When the dimensions allow it, the entire tympanum consists of a single stone (Fig. 1307), otherwise of several courses laid on each other (Fig. 1310). Not rarely are combined the lintel and the slab filling, when the opening is first spanned by a strong beam on which rests the tympanum composed of one or more pieces. On numerous Romanesque and Early Gothic doorways in lower Saxony and on the Rhine, the lintel is enlarged at the middle with a clear understanding of its static problem (Figs. 1308 from churches at Leyden, Billerbeck, etc.). On the church at Sinzig (Fig. 1309, after Redtenbacher) in order to relieve the lintel an open joint has even been left over it, and the tympanum is cut like voussoirs. Larger portals frequently exhibit above the lintel a filling in courses (Fig. 1311). As a splendid example may be taken the principal portal of the church of S. Elisabeth at Marburg. But not rarely are also employed vertical slabs (Fig. 1312), suited to the distribution of the figures as on the cathedral at Wetzlar.

Treatment of the tympanums of simple portals.

Only in very simple examples has the filling remained plain, but as a rule is it ornamented in different ways, and indeed on works in the Romanesque style. The simplest mode of ornamentation forms on the surface wrought crosses, circles or quatrefoil, whose outline is formed by a chamfer or moulding, its ground being either plain or filled by rosettes and foliage, or a symbolical relief like the Lamb of God. Sometimes such rosettes or o other forms in relief project free, where however a like projection accompanies the outer edge of the tympanum concentric with the arch, and either also continues along the lower horizontal line, or stops on the innermost part of the jamb. The lower edge of the slab is simply cut squara or is formed with a projecting moulding. Also sometimes that moulded edge extends over the tympanum in a trefoil arch.

A richer treatment of the tympanum results from a digure representation covering its entire sufface within that enclosure, by scrollwork as in Fig. 1290, by a tapestry pattern or by tracery. The last arrangement may be termed that most unsuited, w when it assumes considerable richness as on certain Late Gothic works and particularly in brickwork (Essenwein, Norddeautsche Ziegelbauten, Adler, etc.), and does not serve to enclose panels separated otherwise or for a window opened in the tympanum. Generally and especially for new works to be executed to economize tracery as much as possible, and to prefer any other mode of d decoration to that, where it does not concern a really structural purpose or even best correspond to the character of tracery.

Treatment of tympanum over double doorways.

More complicated arrangementr arise for those double doorways separated by a middle pier, that are peculiar to the greatest designs of portals. Here we first find the figure above the middle pier already mentioned on p. 546, that either stands on a little column projecting from it ir a corbel and fills the middle of the tympanum. For further filling it are often found two smaller side figures, that are wrought in relief, from the thickness of the tympanum, or are likewise placed free on inserted corbels. The ground behind these figures on the west portal of S. Elisabeth's church is filled by extremely beautiful scrollwork, that consists of vines on the right of the principal figure and of roses on the left.

Another more geometrical treatment consists in this, that blind arches extend from the middle pier to the wall pier forming the strike above the likewise rectangular openings for the doors, so that in the panels indeed by them are carved two side figures in relief out of the thickness of the blind arches. Such an arrangement is found on S. Cyriacus at Duderstadt, (Note), where over the principal figure a canopy is also inserted in the tympanum, and the ground of the tympanum above the blind arches b beside the middle figure and the canopy as well as under the p portal arch is filled by scrollwork.

Note. Statz und Ungewitter, Gothisches Musterbuch.

On the south portal of the church in Volksmarsen on the contrary, these blind arches over the door openings change onto actual perforations, so that here is no space for those side figures. Therefore free columns are placed before the jambs in the same manner as before the middle pier, which bear the side figures, here the princes of the apostles. The latter also come to stand at the same height as the principal figure and are covered by canopies, which at the same time supply starting points for the portal gable, while the canopy of the middle figure of the tympanum is inserted beneath the keystone of the portal arch. On the continuous horixontal line of the posttion of the figures is based the extremely quiet and clear effect of this arrangement. On the contrary on other portals the columns on which the figures stand are kept lower, so that the middle figure stands higher (Fig. 1300).

The arrangements mentioned are all based on the upward transfer of the sculptured ornamentation of the jambs peculiar to t the greater portal designs, to the tympanum and the division of height corresponding thereto, while on the other works, likewise of moderate size, as on the south portal at Colmar, the jambs are only formed by the little columns, and the tympanum receives its own relief ornament. But these different modes of treatment afford substantial proof, how intelligent was the mediaeval architect of the earlier oeriod, in inventing the system most suitable for the dimensions, and how far all attempts were from him, that weakened great proportions by the repetition in little dimensions.

Here not enough can be attributed to later pressure, since t the last endeavor, the carrying out of an unlimited proportion,

still appears on certain portals of the later periods. Therefore we mention here the chapel added to the Frankenberg church in the 15 th century, which with all magnificence and purityyin the formation of the details, yet sins in that it reproduces the entire arrangement of the portals of Strasburg and Cologne in small dimensions.

Reliefs in the tympanum.

Comprising all, therefore we might regard life size as the smallest dimensions for the figures on the jambs, and regard 1 them as restricted to such dimensions, which do not require the figures to rise above the height of the springing, and thereby allow a pedestal under it of half the height. In such dimensions also then the decoration of the tympanum again occupies an entirely independent position, and consists of a series of scenes represented in relief, that relate to the holy person to whom the portal is dedicated and the endeavor is severely arranged. As we stated, the size of the tympanum, whose height is still increased by stilting the arch, excludes its formation by one slab, there results from this an arrangement of separate representations in different rows over each other. Hence each slab has a continuous series of figures with one beneath, moulding plain or decorated by leaves, or a series of canopies is carved. The latter serve at the same time as a base for the figures on the same slab, and as a covering for those underneath. It may here be an advantage to carry out the division in height found on the jamb also on the tympanum. Such an example is offered by the side portal of the west facade at Amiens, where the udderside of the lower slab at the height of the canopy projecting from the column of the jamb (p. 544), and the top lies in that of the capital, so that its abacus extends on that slab with the same or a harmonizing member, thus characterizing the agreement in height. In the horizontal division cay be caused a greater variation, that in the middle in contrast to the broad one may be employed a high placed slab set on edge with a corresponding relief.

To the representations we shall return later, on the mode of treatment may it only be stated, that the vicinity of the high projecting courses of the arch with their boldly effective figures with canopies in the hollows, also require a strong relief in the sculptures of the tympanum and a crowded position of the

separate figures.

3. External enclosure and crowning of the portal.

Crowning moulding.

According to the simplest arrangement of portals with jambs developed in the thickness of the wall are so placed in the face of the wall that at each side remains a plain part of the wall. As the nearest ornament then results an addition of a concentric projecting hood moulding, which with a simple profile can be ornamented by foliage in the cavetto, and on whose arrangement and solution all necessary has been said on p. 352. The use of this results almost of itself, when the hood moulding, instead of passing above the arch joins it, that most simply c can be produced by making it concentric. Instead of this is generally found a rectangular or gabled carrying around of the cornice concerned, the last generally being stilted vertically according to the proportion of height.

Finials and tracery gables.

Meantime these forms of crowning do not require the motive of the cornice, but can also be independent, so that their springings may be corbelled out at the height of the base line of the arch, terminate in a scroll or any other projecting sculpture, run to a head or an animal projecting from the face of the wall. Such a solution results very easily from the arrangement of the portal sculpture in Volksmarsen with canopies over the side figures described on p. 550, where the gable cornice either as there continues in a horizontal direction by a bend, or forms its own line of inclination, so that any proportion of height may be attained thereby. Now so that pinnacles or entire finials may stand in the required position on the canopies, the effect of finials and tracery gables is obtained. Thus also are found in that position simple finials on columns, corbels or priers. At least on the better works the finials and their supports are only made light and purely ornamental, excluding all conception of structural importance not really existing. Special weight might be laid thereon, in view of many later experiments, where the massive buttresses were placed before the portal jambs, but whose projection is nowise utilized for a deeper form of the portal arch, and which therefore have nothing more to do than to stand as guards beside the doorway. If it be allowed to men-

mention the restoration of Cologne cathedral otherwise than a model, we might designate that mighty development of pinnacles between the portal jambs of the transepts and the buttresses separating the latter from their side aisles as examples of designs better avoided, but at the same time another point comes into consideration here, to which we called attention on p.556.

Increasing the depth of jambs of the arch.

Meanwhile such buttresses may have their use, if arches are turned between them flush with their fronts, that accordingly increase the depth of the portal arch and of the covered space before the doorway. Thereby arises a part of the portal projecting from the face of the wall, and that crowning like a gable becomes an actual roof of the projection. This arrangement is then commonly found, among others on certain Westphalian works in a way, that part of the buttress rising above the beginning of the gable assumes the form of a slightly corbelled pinnacle, or in the simplest case is entirely omitted, so that the entire projection must lie beneath the gable. On the treatment of this gable with covering cornice, angle ornaments and crowning applies everything generally said above concerning gables and tracery gables.

There should not be omitted here the portal crowning of the Mariastiegen church at Vienna (beginning of 15 th century), that instead of tracery gables has a pentagonal or hexagonal canopy, that partly lies in the thickness of the wall and is partly free before the external face.

Simple porches.

By increasing the projection of the buttresses is found the means of increasing the depth and importance of the entire enclosure, and thus passed gradually to the development of a porch. By covering the plain surfaces of the piers, which are ornamented by blind arches, little columns placed before them or by figures, or that again can be strengthened by angle buttresses, especially if the arrangement of the vaults permit such, this is capable of every expression from the greatest simplicity to the highest richness.

It further leads to those portal structures peculiar to Italian architecture, which consist of two columns standing before the wall and connected with it by architraves, where a tunnel vault is turned from one architrave to the other. The spreading

of the vault is indeed there prevented by iron ties as generally in the South, and so that opposed to the stress of the arch slender columns are possible. By an enlargement of the columns properly permissible in our style by varied arrangements of coupled columns, by connection with the buttresses at the angles, substituting or supporteng that architrave by arches, introducing the cross vault instead of the tunnel vault, result the most diverse transformations of the motives mentioned as corresponding to the principles of the Gothic style.

Relations of the portal to the buttresses.

By a continuation of the form of the jambs of the portal to the nearest buttresses belonging to the structural system of t the entire work, and the complete filling of the space between the buttresses thereby obtained, results then the just explained arrangement peculiar to the richer and greater works.

According to the proportion of the buttresses to the whole a and to the width of the portal, four cases are here possible.

1. The jamb reaches the front of the buttress in the once commenced stepped or splayed ground form with its columns placed before it. (Fig. 1313).

2. The jamb would not reach them on account of the small projection of the buttresses, and thereby would become necessary an addition to the width of the buttress to the height of the portal gable or an interruption of the form of the jamb by means of a plain part of the wall, about according to the plan given in Fig. 1313 a, whereby the arches of the separate parts m must not exactly be concentric.

3. The sides of the buttresses already extend much earlier from the form of the jambs, thus within the outer corners (Fig. 1313 b), so that the buttresses form a strong projection.

4. In the last case a vault is between the buttresses, as on the transept portal at Chalons (Fig. 932) and the west portals of Amiens (Fig. 1214).

Combination of adjacent portals.

But we must here go more fully into the mode of treatment of the last mentioned works. On both the columns of the portal jambs project at the sides and beyond the fronts of the buttresses (Fig. 1314). Now in Amiens the columns bear on their capitals richly moulded ribs concentric with the portal arches, between which appears the tunnel vault, and that farthest in front

the terminal is beset by a system of little suspended arches, while in Chalons the capitals of the columns are connected by a continuous moulding about as in the manner shown in Fig. 1298, on which the tunnel vault has its bearing, no longer divided by ribs, but only bordered in front by a projecting band resting on the capitals of the columns concerned. But the surface of this in each half is animated by three rows od six blind ribs on each, which must at the top ridge be according to the way shown in Fig. 1315. The portal mentioned above as well as that at Rheims and many others as seen in Fig. 1314 have an extremely rich arrangement, in that the system of columns of the porch continue to the fronts of the buttresses.

Even thereby the united character of the triple portal structure is most decidedly expressed. Thus it forms an independent part of the height corresponding to the height of the side aisles, and to the further develop om the buttresses seems opposed, in contrast to the usual arrangement of German works, according to which the buttresses in entirely independent form extend down to the ground and produce a decided division of the three portals.

To create a greater depth for the entire plan of the portals, the depth of the buttresses can be increased, and accordingly if the oblique direction of the jambs as in Fig. 1313 goes to the angle a of the proper buttresses, these continue in that increased depth of the buttresses as given by dotted lines, so that the width of the buttress diminished. That addition to the depth then passes into massive little towers placed directly above the height of the springings of the portal arches, so that even thereby its entire relation to the portal structure is expres

Gable roof over portals.

The projection that the portal arches accordingly form before the upper face of the wall requires a separate covering, attained by gable roofs on older works, so that the cross section through the crown of the portal arch assumes about the form shown in Fig. 1316. With a considerable projection of the portal would however occur a considerable decrease of the dimensions, and t the rectangle a b c d would be made solid.

Detached gable walls.

Accordingly there results the design of a gable wall e f resting only on the foremost arch, whose thickness is only required

by its own condition of stability and behind it being the terrace c d with surface lying at the height of the internal floor of the triforium, and that by means of the passage through the buttress is in connection with the passage at the base of the side aisle roof. But since the width of this terrace according to the projection of the portal structure may exceed the dimension required for access, it is next to cover this surplus width by a separate shed roof adjoining the gable wall and sloping down to the passage described above. This arrangement is found on the cathedral at Rheims, formed about according to Fig.131, whereby that shed roof c d is placed on a detached pier a, which is connected with the gable wall by a header b and so increases the stability of the latter. In similar works the gable is also then omitted, and the portal structure then terminates with the passage alone.

Removal of water.

Removal of water from the floor of the passage can be effected in different ways. In the simplest case as in Rheims, a spout can be carried through the buttress, ending before its middle. On the contrary in Amiens the perforation of the buttress is avoided, the water spouts being doubled and thus lying at b both sides of the buttress, and are arranged at the base of the gable extending over the portal. Instead of these the passage can also be carried around the offset of the upper part of the buttress, thereby arranging spouts accessible from the sides.

The inclination of the gable is sometimes small on the older works, rising little more than an angle of 45°, and meantime b becomes steeper on later works in the measure, that the portals themselves have lost size and importance.

Treatment of tympanum of gable.

With these small inclinations the gable tympanums themselves are generally left plain, or only ornamented by a circle with cusps or a polyfoil, animated by three little rosettes in its spandrels. The enclosure of these figures, the ends of the cusps, etc were usually decorated by foliage.

Richer forms then result by its division into mullions and a system of tracery. In the first lase the panels between the mullions can be again filled by figures, which are related to the meaning of the representations on the tympanum of the arch, so that the principal representation on the gable found in a great

blind niche covered by a canopy forms the conclusion of the entire cycle of figures. Of special beauty is the gable area on the principal portal of Strasburg minster.

In the second case with the resolution of the gable into a s system of tracery, its separate panels may be filled by figures. A particularly good effect is produced if it rises with heads, arms, wings or even the ends of drapery above the bars enclosing the panels of tracery, thus breaking the geometrical scheme. A particularly rich example of this kind is shown by the portal on the north side of the cathedral at Rouen.

Treatment of the wall surfaces beside narrow portals.

We have already mentioned above the different arrangements, by which where the conditions do not permit a principal window filling the entire width between the buttresses, the effect corresponding to this arrangement will at least be striven for. T The same case may also occur for portals of available height t that reacts on the width, and lead to the most varied solutions. The entirel width may be divided in two parts, so that the treatment of the elevation comes to that of two portals beside each other. This is found on the west front of the cathedral of Laon.

Another more ornamental arrangement consists in this, that t the space between the buttresses and the portal is filled by b blind tracery, that is either arranged according to the mode of the inner arcades, thus only going to about the height of the lintel of the doorway, or it occupies the entire surface up to the next horizontal division, and thus also continues above the gable of the portal as on Strasburg minster. Here this blind tracery becomes free standing high arches lying before the face of the wall, that bears the floor of the passage found beneath the wheel window, while the tracery gable of the portal lies on but two slender mullions of this arcade, extended in piers resolved into rich forms of finials.

We must contrast the Strasburg arrangement again with that of the Cologne transept portals, where the space concerned is fully occupied by this massive development of the pinnacles, so that where in Strasburg resulted a lightening and economy of mass by the arcades, here was produced a considerable increase in mass.

Further there belongs here also that arrangement, whereby the architecture of the portal continues in blind tracery of the b buttresses, so that portal and blind work have equal heights,

that are bordered by the hood moulding above them.

Thus the south side portal of Freiberg minster exhibits the arrangement of three arches occupying the entire width, supported by columns and crowned by tracery gables, of which the middle one forms the proper with a further extension of little jamb columns and arches, while thus at both sides are separated in two divisions by little secondary columns and arches. Above is then found the window of the side aisle.

Windows over the portals.

If the doorways first only open the wall beneath the window story, the upper part of a great portal structure may entirely or partly close the window, as shown by the example of Chalons (Fig. 932). With smaller dimensions of the whole these parts m may even rise into the triforium or farther into the clearstory, and then also may restrict the design of the latter windows. T The same case occurs for portals found in the side aisles, or also in transept portals found in churches with aisles of equal heights. In such cases is generally found over each portal a simplified arrangement of the window, thus on the north transept of Gelnhausen, with all three round windows placed in an equilateral triangle, or as on the south window of S. Blasien in Mühlhausen, with a single great wheel window or even a small round window, as on the south side aisle of the church at Frankenberg, or with one of less breadth and pointed above the portal gable. Finally often with greater extension of the height of t the portal, the window above it entirely disappears as on the south side aisle of the church in Volksmarsen.

But the converse arrangement also occurs, that the window crowds the portal, at least in regard to the treatment, so that the latter only forms a subordinate division of the former. In this case the window jambs extend to the ground or down to a plinth near it, and the window sill at the same time becomes t the lintel of the doorway, as on S. Boniface's church at Fritzlar. Yet sometimes the doorway under the window sill is still spanned by a pointed arch, as on the north portal of the church at Wolfhagen, or finally over the latter is omitted the window sill, so that the window mullions rest directly on the pointed arch as on S. Jacobi at Mühlhausen.

A similar arrangement is sometimes found in this way, that above the lintel of the doorway is placed a window of less height,

somewhat like a transom, the entire part then being filled by piers resolved into finials, and bordered above by a tracery gable, over which is still the proper larger church window, that finds its place as on the church at Haina. Meanwhile all these forms belong first to the 14 th century and sometimes produce no good effect by too great slenderness of proportions.

4. Porches.

Smaller porches and doorways.

A distinction must be made between little porches directly adjoining the portal, that besides their architectural problem have only the practical one of affording to a few men shelter from the weather, and these porticos or rooms like halls, that afford space for a great assemblage and can even increase to church vestibules.

Porches between buttresses.

To the former already lead the extensions of the jambs of the doorway already mentioned on p. 553, that extend as short tunnel vaults between the buttresses. These still appear as directly parts of the portal, and thus appears a separation when the doorway is narrow and still over the entire space from one buttress to the other is turned a tunnel or rectangular cross vault, which is terminated in front by a cross arch set back from the front of the buttresses with the gable or hip roof found above it.

Greater depth of these porches may be obtained by increasing the depths of the buttresses, that may also be made wider according to the span of the porch. Arrangements of this kind are found not only between buttresses, but also in the angles between the choir and the projection of the side aisles or transepts, just as in the angle between side aisle and western facade, etc.

Porches with free middle or corner piers.

The strongly oblong mround form of such porches may by one or more intermediate piers be connected by arches into separate bays approximating a square.

Greater depth with less width can be obtained by detached corner piers instead of projecting buttresses. A very beautiful p porch of this kind is found before the north transept of the cathedral of Magdeburg, which is covered by two interesting gable roofs over the cross vault, and opens in front by two doorways spanned horizontally, where then the tympanum of the side

arch over each double doorway is opened by a wheel window, and slender finials extend above the vertices of the gables from the angle buttresses.

Triangular porches.

A peculiar porch is forded by the portal structure on the north transept of the Erfurt collegiate church which is plan is arranged as an equilateral triangle, that even takes as a base t the width of this transept, while the other two sides are opened by rich and great portals entirely in the system prevailing in the 14 th century for such designs. The present structure w with its second story, as definitely recognized, originated by a departure from the original plan.

An open triangular porch is further found before the principal portal of the cathedral of Regensburg.

Larger independent porticos.

Origin of porticos.

The custom of building larger porticos before the principal entrances of churches extends back into the earliest times of Christianity. To receive penitents and converts was required a vestibule of moderate extent, the narthex, that was often placed in connection with the paradise, a forecourt planted with trees, and this was surrounded by colonnades and generally had a fountain in the middle. The forecourt gradually disappeared, but the portico remained till the 12 th century and generally was before the west facade, extendind for its entire breadth; after the 13 th century it was less common before the west portal, but generally porticos for these were erected before the side doors of the transepts and of the nave. (Cathedralsat Lübeck, Kammin and Riga).

The porticos were covered by vaults or wooden ceilings, the smaller ones were mostly open, but the larger and especially t the earlier ones were closed at the sides, and these sometimes became important three aisled churches (Vezelay), that even in Romanesque times already occurred in two stories (Tournus). S Such great prechurches seem to have been less built in Germany, but on the contrary it is remarkable, that still two forecourts surrounded by columns have been preserved at Essen and at Laach.

One story porticos.

A very beautiful example of the closed portico is presented by the west portico of the collegiate church at Fritzlar, dating

from the early 13 th century, which in the interior bears net a strong Romanesque stamp on the vaults and piers, but on the exterior frequently exhibits in windows and doorways the forms of Early Gothic, indeed in charming treatment.

Open porticos occur on French works, partly in very rich development. Thus such a one is found belonging to the beginning of the 14 th century, before the west facade of the cathedral of Noyon and extending its full width, its three bays corresponding to the middle and side aisles and the width of the towers.

The picturesque effect of this arrangement is substantially enhanced, because the thrust of the vault on the front piers is not opposed by directly strengthening them, but by detached buttresses set a little back, connected with the former by flying buttresses. The entire portico is covered by a terrace, so that a tracery balustrade forms its upper termination.

Two story porticos.

According to the special requirements, the arrangement of a second story above the terrace may be preferable, and the space thus obtained in it may serve for either to receive the organ or the arrangement of a separate hall, or finally for a loggia opening into the church.

An arrangement of this kind is found in the Frauen church at Nuremberg, where to the rectangular portico is added a polygonal structure, that has approximately the same height as the church, so that its roof intersects the gable of the church.

But far greater importance is claimed for the portico building of Notre Dame in Dijon, which like that at Noyon extends in three aisles over the entire west facade, and by its two upper arcades separated by a high frieze entirely conceals that. Viollet-le-Duc states that these upper stories were to serve as connecting two towers before the side aisles but never built and not in the original design, by which certainly the west side would have had an effect differing from the present one, corresponding more to a secular building. Yet aside from that must one lament the omission of one of the noblest works of art exactly corresponding to the construction of the whole on the church mentioned, yet of charming beauty.

At S. Benigne in Dijon is found a portico in modest dimensions, that is made a little wider than the middle aisle, and whose superstructure obens by a low arcade on the exterior.

Porticos beneath the towers.

The numerous open or closed vestibules placed under a tower or between two western towers indeed do not bear the character of separate structures, but by their use are also to be counted with porticos.

The arrangement of porticos certainly at present is not a direct need. Yet their introduction, and particularly if enclosed, would dispense with those ugly wind porches encroaching on the interior, that in recent times have been added ho most old churches. Further that also these are capable of correct treatment in style are nowise held to the opposed form now common is proved by many Renaissance works. A far more worthy development c could have been reached in the Gothic style, whose superiority especially in the development of wood construction would consciously or unconsciously be admitted by great many of its present opponents.

Meanwhile also those open porticos, and especially for such churches to which are added outside societies, dispense with the use of the tavern at least before the beginning of divine service, and that they enrich the effect of the whole by a picturesque tendency. It is self-evident, that in cases of the last kind, vaulting in stone is not a necessity, but that wood construction may rather appear here with advantage.

5. Sculptured ornamentation of portals.

In the development of the different parts of the portal, we have also described the arrangement of the sculptured ornamentation, and it still remains to briefly indicate also the objects for representation according to the principles of Christian iconography.

It is first of all to be emphasized, that the sculptures of the portal form a connected whole, and as such it must stand in direct relation to the Lord, the Holy Virgin or the Saint to w whom the portal is dedicated. This unity of the sculptured representations continued on all mediaeval portals from the simplest to the richest arrangement and generally extends to the entire facade.

Simple portals.

In the simplest cases in which sculptures are found only on the tympanum, these exhibit Christ surrounded by the symbols of the evangelists, or Christ as the judge of the world with the

intereessors Maria and John. If the portal relates to the Holy Virgin, then is found here Maria in clory with praying angels, or Maria accedted as queen of the apostles according to the litany, who are then represented by the apostolic princes Peter and Paul. A frequently recurring representation is also the coronation of Maria by Christ.

If the portal is dedicated to one of the saints, then it is a scene from his life, indeed as a rule it is the most popular one that is represented, thus for S. George is the fight with the dragon, for S. Martin the dividing of his cloak, etc.

Portals of great cathedrals.

Far more complex is the arrangement of the figures on the portals of the great cathedrals.

Here the titular figure stands at the middle pier, thus on all portals dedicated to Christ is the triumphing Saviour himself or the Mother of God. On the columns of the jamb or even in the jamb stand the ancestors of the Lord, David, Solomon, etc., and further those prophets that intimated hhe redemption, or in general Old Testament figures presignifying the Sacrifice, like A Abhaham, Melchisedech, etc.

Commonly are further found the wise and foolish virgins or t the cardinal virtues, and as end figures of the entire series the Church and the Synagogue, or Adam and Eve as the middle ones.

The representations on the tympanum then comprise the story of the Lord with the Passion in greater or smaller extent also terminating with the Crucifixion, the Ascent to Heaven, or the Last Judgment. On the portal of the north side of the cathedral of Rouen are found the meaning and the origin of the apostolic confession of faith and also in this the Passion. Sometimes the f final representation is placed in the field of the gable or even higher on the facade. Thus on the portal gable at Strasburg two large spaces are found aboev each other, the lower containing Solomon enthroned and the upper the Queen of Heaven, while in the arcade found in the upper half of the wheel window are the apostles with Maria as their queen, and in a vesica rising therefrom is represented the enthroned Saviour. On the tracery gable crowning those arcades stand the choir of angels. Also further the story between the towers opened by two arched openings crowned by tracery gables also serves for the further development of the sculptured decorations in the following way. On the order

of piers turned toward the towers are represented on each two evangelist above each other in human form with heads of the symbolical animals. On the same piers above the junctions of the tracery gables stand angels with the implements of the Passion, in the middle between the tracery gables sits Christ as Judge of the world, and in the spaces enclosed by the gables are the intercessors Maria and John. But there the spandrels of the gables rise as foliage the tombs with figures of the resurrected, and at both sides of the crowning gables, also four in number, stand the angels of the Judgment with the Oliphant.

Also sometimes the Last Judgment forms the sole ornament of the sculptures of the tympanum as on the south portal at Colmar. For here within the pointed arch forming the principal shape of the tympanum is cut a round arch of equal span in the surface. (See Gothisches Musterbuch). In the middle of the latter stands a bishop, who rejects those coming from the right, while he receives those approaching from the left. In the space remaining between the round and pointed arches is separated a middle area in which Christ is enthroned as Judge of the world, surrounded by the angels of the Passion and the Judgment. In the spandrel at the right of the Lord is then found the ascent of the blessed into heaven, while that on the left is again divided in two spaces, and that nearest the middle has the resurrection from the grave, and the lower one contains the punishment in hell; the last is represented by the mouth of a colossal beast, in which is placed the damned.

The sculptors in the courses of the portal arch as a rule place the choir of nine angels, the apostles, the evangelists, saints, prophets, fathers of the Church, virtues and vices, or t the tree of Jesse, in brief the representations of the heavenly hierarchy.

Conversely the various panels of the plinth are rather devoted to worldly impulses and earthly conditions. Accordingly they contain either in the arcades or on the plinth the series of animals, seasons of the year, arts and sciences, representations of agriculture and hunting, sometimes even merry scenes (Fig.1306).

6. Portals of brick.

Use of cut stone.

In the 12 th and 13 th centuries, when brick construction rapidly extended in the German low-lying plains and in the Slavonic

provinces influenced by them, men remained in a certain degree still under the traditions of cut stone construction; where this occurred, the richer parts of the building and especially the portals were entirely in cut stone; an exception is found in the limestone portal given in Fig. 1286 for the cathedral executed in brick at Riga in the beginning of the 13 th century.

Men proceed one step farther, when as on the beautiful Romanesque portal at Seehausen the stepped treatment of jambs and arches is in moulded bricks, while the inserted columns with capitals and bases as well as the rounds extending in the arches from the columns are executed in cut stone.

The arrangement of such stone jambscolumns, that can be placed either before an oblique surface or in masonry steps of the jambs, is also in place where the arch entirely consists of brick, and it is particularly effective by the contrast of colors. The small size of the brick courses causes, that where possible two courses of bricks stand on a column, either according to Fig. 1318 or Fig. 1319 (see next page).

Finally such portals are also not rare, on which only the bases and capitals with the impost moulding are of natural stone, but the jambs and arches are entirely built of brick. All Cut stone bonded with the brick masonry is to be wrought with a rectangular projection of the greatest required dimensions, that enters the wall so that the courses of brick always stop against vertical end joints and nowhere against mouldings; from this may result an ornamental motive at certain points as shown by Fig.1320).

Portals entirely of brick.

Portals without the aid of cut stone also appear already in the earliest time of brick architecture, and predominate in the middle and later times. It is interesting to examine how at first brick architecture was under the ban of the cut stone forms, but very soon freed itself from these so far, as the particular qualities of the material indicated.

Members of jambs and arches.

On the earliest jambs of doorways it still occurred that the little columns were placed without bonding in the angles of the steps (Fig. 1321), they were made of round clay cylinders, and on the church at Arendsee in the Mark. For slender columns of small diameters, these could not retain the technics of cut stone standing on end, and men bonded the moulded bricks of the c

columns, as by the same portal at Arondsee besides the larger free are also shown such slender banded shafts of columns. For bonding were soon formed dovetail projections on the cylinder on alternate sides and entered the depths of the jamb courses (Figs. 1322 and 1322 a). In the arch the rounds turned in the same direction. (Fig. 1322 a). The diameter of such little columns or rounds mostly amounts to a half brick or 14 to 15 cm, yet there often occur smaller sizes of 1/3 brick or 9 to 11 cm.

The projecting angles of the stepped jambs at the beginning were formed as for cut stone, but soon the convenient technics of moulded bricks and the dull effect of the clay soon led to arranging boldly curved mouldings beside each other, that finally in the later time received such deep recesses, that they could not be wrought usually in cut stone, while they were easily possible in bricks with suitable joints. By increasing the animated sequence of mouldings the simple round little columns receded or entirely vanished (Figs. 1323 to 1324 a and also previous Figs. 958, 959).

Treatment of smaller portals.

At the same time the capitals and bases lost importance and one impost moulding remained only on rich portals till the later time, and the smaller doorways already quite easily assumed a definitely simplified expression. They almost always received as base a plain granite sill on whose upper surface the moulded bricks started abruptly and continued in the arlh without any further separation. The entire portal was enclosed by two or three moulded bricks or even but one if necessary, and thereby presented a play of mouldings, only to be obtained in stone by costly stonecutting. Thus the brick portals exhibit an ever increased adaption to the nature of the building material.

Treatment of the principal portals.

Yet the principal portals did not restrict themselves to such a simple development, but received richer alternating moulded bricks and even great moulded blocks in clay; even foliage and figures with canopies were sometimes modeled as on the castle church at Marienberg. But in general strongly projecting reliefs were forbidden, for they might assume the appearance of affected art. In their places appeared twisted rounds (Fig. 954 a), terra cotta plaques in flat relief, flat patterns composed of moulded bricks and especially treatment in many colors, among which

glazing occupied the most monumental and prominent place beside the white plastered or painted surfaces.

The glazing of the bricks of the arches and jambs was recommended for its durability, but with this the members built of u unglazed bricks easily had the effect of a certain loamy softness, that was heightened by glazing. On north German brick buildings as a rule the glazing is black, brown, green or yellow.

Tympanum.

The tympanum can also be executed in brickwork with particular richness, ornamental and even figure reliefs are there produced by inserted plaques of terra cotta, that are improved by glazing or painting. Instead of these the representation of the objects by simple surface painting produced a rich and grand effect, a and it was employed by preference, for the locations protected by the depth of the jambs. Meanwhile there was here first of all strongly conventionalized treatment with bold and broad outlines in light colors without much shade tint, since a modern soft manner in connection with the simple and sharply distinct lines of the architecture would have injured their effect too much.

Enclosure of the portal.

For the gable area over the portal is suitable the arrangement of separate panels of circular or quatrefoil shape enclosed by masonry, whose ground can be plastered or filled by plaques of terra cotta, or the entire surface may be divided into vertical blind arches, that can be filled by detached stone figures on corbels or pedestals.

When already in certain later works of brick architecture the execution of tracery gables with the accessories, crockets, etc., is attempted, it is in the nature of the case that such works with exaggerated richness can be made partially possible by means of certain not strictly structural means of fastening, partly only such small dimensions occur, that these must seem puerile in contrast with the usual proportions of a portal. Therefore in case the circumstances do not permit the tracery gable and usually all the more richly ornamented parts to be made of stone, it is better to construct a simple portal gable, whose border according to brick construction consists of a projecting round course; even more natural is it to form a stepped gable. Instead of the gable very frequently occurs an enclosure of the

portal by a moulding broken around in rectangular form (for example the hood moulding), with the filling of the enclosed area by a perforated network of moulded bricks with plastered ground.

7. Door leaves and their fixtures.

Nailed doors.

Nailed doors are preferable in contrast to framed, which came into use on church buildings, since generally in their position in the open air certain advantages over the latter are peculiar to them.

The leaf of the door consists externally of planks abutting against each other or joined by tongues, which are nailed on an internal frame most simply composed of two or more cross pieces and an inclined brace, or of a second layer of planks with joints crossing the former. The nails must be well forged with projecting heads, merely flattened, shaped like the segment of a sphere, or more richly ornamented, and well clinched or riveted on the inside. To prevent the sinking of the nail heads into t the wood in driving, these iron washers are placed under them, that afford another ornamental motive. Nails also may be replaced by bolts, but less well by the so-called lag screws. Although connection by screws was very well known in the middle ages, it was not common for this purpose.

Hooks and bands.

In any case the leaf of the door has a smooth surface outside, and the arrangement and execution of the fixtures determine its ornamental character.

In the simplest way the bands are fastened on the outside of the door, indeed just at those internal cross pieces with two bolts and various nails and coiled at the edge of the leaf of the door (thus in Fig. 1325) and these eyes hang on the kooks that are let into a stone and cast, or fixed immovably in a carefully cut groove in a stone. In the latter mode they are also built in between bricks. Such built-in hooks in the simplest c case have the form in Fig. 1325 a, and they clasp at the plain end behind an ashlar or brick, their length for moderately heavy doors amounting to 30 cm or the length of a brick. Stronger are the split hooks, Fig. 1325 b. The example given from the c cathedral at Riga has at the front end an enlargement like a dowel, that strengthens the projecting end and makes it immovable.

But as a rule the iron bands are placed on the inside of the

door, indeed on those cross pieces (right half of Fig. 1325), while the so-called ornamental bands are nailed on the outside. The hanging bands are first nailed on the cross pieces and the nails are riveted, the ornamental bands are laid thereon and connected with the hanging bands by some bolts, that pass through the entire thickness of the door including the cross pieces, and the nuts on them lie on the inside; afterwards the ornamental bands are further fastened by nails, that are naturally shorter and are not riveted.

In spite of their name the ornamental bands have less a decorative purpose than rather the important function, in common w with the iron bands with shorter nails (Fig. 1232), and holding the planks more firmly and ensuring the door against violent d destruction by the splitting of the planks.

Both the hanging and the ornamental bands consist of iron flats, that extend over nearly the entire width of the leaf of t the door, are forged thinner at the ends, are split at the ends in the simplest cases, and both parts are curved (Fig. 1326). By division into three parts results at the end the form of the heraldic lily, (Fig. 1327 .). By more divisions are produced t the most varied leaf or rosette forms, into which we cannot go farther here. In the same way by splitting certain parts at the side and bending those parts, by forging the ends thinner and hammering out the sharper edge lines are animated the straight outlines of the bar. Fig. 1327 shows different modes of executing this kind, and at the same time makes clear the method of working, for each of the little branches a is taken from the m mass of the bar as seen at b. Treatment of this kind, which is proper only for a small width of bar is especially required for the hanging placed on the inner cross piece, while the ornamental bands spreading over a great surface admit of freer forms. This can be formed by reducing the number of splits whereby their length naturally increases, and where the separate bars, if the size permits, can be treated like Fig. 1327 or be further divided. Other forms result by division of the band from the beginning into two or more bars, which either branch from the entire band, or at their junction can be welded together. Figs. 1328 and then 1329 to 1331 exhibit several other forms of this kind. A further ornamentation may the separate parts receive by lines cut while cold, by which the finest engraving can be rep-

represented, and further by chasing the separate leaves and raising a flat modeling by hammering.

Real masterpieces of this ornamentation are the bands of the leaves of the doors of the northwest portal of the cathedral of Paris, that in the wealth of invention and sharpness of execution emulates the most beautiful work created in a pliant material.

If atleast two hangers are required for each leaf of the door, then for a considerable height of it yet a third and even a fourth may be added. The ornamental bands as a rule take their principal character from the horizontal direction of the hinge bars, meantime these are sometimes formed also as a scrollwork moving outward from a central point, freer and more like a rosette. Excellent is the effect of the bands placed on the middle of the leaf, which have the purpose of further strengthening the door.

From what has been said follows, that the indicated mode of treatment proceeded from the work of the smith, and that an imitation of these forms in cast iron would be nonsense. If the latter material were generally suitable for hinges and ornamental bands, which is not the case on account of its fragility, then in every case an entirely different treatment of the form would be required. Likewise must the cutting of the ornamental bands from sheet tin, as sometimes attempted in recent times, must be termed a substitute entirely lacking the desired effect, since the reduction of thickness at the ends cannot be executed in sheet metal, whose nature consists in the uniform thickness, and therefore demands an entirely different treatment. The covering of the edges as well as the entire or partial covering of the door with sheet metal naturally can be regarded as a justifiable strengthening.

But it also does not suffice for the wrought iron band, as it must be with the exception of what is mentioned above, is laid out while cold and prepared in the fire under the hammer, and the file must be entirely excluded, even with the danger that the drawing is not very sharply reproduced, which is unavoidable with the slight preparation in art at this day. We know from experience how hard it is to omit the easy assistance of filing, thereby rejecting the smoothness of the surface so much favored and the elegance of the edges formed. Meantime aside from all further use then appears the painting of the iron work as a right of necessity, since every mark of the file becomes a spot

of rust. But then if the manual skill at command makes the file and painting a necessity, then first of all is now to be avoided the favorite blue color, which blue imitates mouldy iron without result, and thereby produces an ugly effect; black or brown ochre is better.

Door lock.

The lock is to be set on the inside of the door, and if the working of the bolt is to be accurate, the case is to be made of one piece if possible, thus showing the form given in cross section in Fig. 1333 with slopind sides and flat adjacent margins, oh at least the fronts of the surface must be covered by a piece c riveted on in Fig. 1333 a. The arrangement of a latch lock is unnecessary and the ordinary so-called German lock with a thumb piece beneath corresponds to the purpose in a more perfect manner.

As to the hinge band corresponds the ornamental band, so there corresponds to the inside case of the lock the lock plate set on the outside of the door, which also covers the rivets of the nails for fastening the case of the lock, or it serwes as a base for schews passing through the thickness of the door and the case. As a rule this plate has the form of a rectangle with slightly curved edges and the lower end is extended below (Fig. 1334). Through it is cut the keyhole, that is bordered by an applied scroll of thin iron (b in Fig. 1334). The latter also fills the essential purpose of guiding the key to the keyhole at night.

In the earliest time not all doors were furnished with locks, but they were in part fastened inside by bars or logs. Such a beam 20 cm thick is still well preserved and rests in its place in the wall behind the door of the church at Wolmar in Livland, dating from the beginning of the 13 th century.

Ring and fastening.

To the fixture mentioned is added also the ring for pulling the door, fixed at the middle of the leaf and at a height of a about 1 to 1.2 m. On folding doors without a middle post this naturally comes only on the leaf on which is placed the lock.

The ring turns in an eye a as shown in Figs. 1335, 1335 a, which passes through the door and is clinched inside. Under it is placed a plate b, cut out in the form of a rosette, and sometimes perforated, where certain parts are wrought and nailed on the outside of the door. Sometimes two plates are placed on each

other, and thus more complex perforations are made possible. In richer execution is found here a bronze lion's head that holds the ring between its teeth within a circular frame nailed to the door. The ring sometimes takes the form given in Fig. 1 1336 and then turns in the eye on a pin. Chiefly on inner doors, it is further usually replaced by a handle, either like Fig. 1337, made ofa single piece of iron with ends forged wider and nailed on, or like Fig. 1338 is made of two horizontal pieces a passing through the thickness of the door and riveted inside, under which are placed the plates b, with a vertical handle c tenoned into the former, that is round or turned; it can be made of a different material like wood.

To the fixtures mentioned then are added the bolts entering the door sill on the permanently fastened leaf.

Further the edge of the ring is sometimes protected by a metal strip laid on it and cut out of a leaf pattern, which supplies a very effective ornamental motive.

Rebate strike.

For double doors without a middle post the leaves strike a rebate very simply arranged on the doors (Fig. 1339), a strike b batton is required for more perfect closing, that is fastened on the leaf first opened on which is placed the lock, and fastened by iron nails with visible heads. This mode of fastening so far prescribes its form, that it must have a surface suitable for driving the nails.

It is accordingly next either to only bevel or cove the edge, or after locating the nails to determine the entire form about as in Fig. 1340, or finally to ornament the front surface by flat carved scrollwork, which is then to be so arranged that t the nails may pass through it in a proper way. On the inside of the leaf of the door the case of the lock presents the arrangement of a continuous batton. Therefnre it must either be omitted, or be divided in two parts by the lock, but the case of the latter is furnished with an iron band a in Fig. 1335 b corresponding to the batton, by which the joint produced between it and the strike on the other leaf is closed. This band may further be strengthened by projecting edges and perforated in various ways to form a rich decoration.

Doors with framework.

Instead of the before mentioned composition of the inner door

frame of pieces, this may consist of a regular framework, in t this manner giving opportunity for richer forms, both in the t treatment of the frame, the grooving of its edge, etc., as also that the panels contained in the framework may be richly ornamented or perforated panels of wood or a nobler material be arranged, as on S. Maria im Capitol in Cologne, whose edeges extend under the frame and are held thereby. This mode of execution f forms the transition to the paneled doors.

If we have hitherto assumed the plane side of the door to be turned outside, there is still found sometimes the converse arrangement, so that the framework forms the external side. Likewise in this case the hinges can lie outside and be set on the horizontal rails; still the different branches of the hinge plate must not have a shape exceeding the breadth of the frame, and corner bands like Fig. 1341 may be employed with advantage.

For those important widths of leaves, such as result from the dimensions of larger works, it is advantageous for easy access to allow only a part of a leaf to open for ordinary use. For t this purpose either the ornamental band or the hinge will be divided by a hinge joint, according as the little door is to open inward or outward.

Richer treatment of doors by painting and overlays.

For a richer treatment of internal doors it is self-evident that painting may pe very effective. Here is applicable with great advantage that mode of treatment peculiar to the late middle ages, where a simple foliage or tracery band extending around on a black ground is so painted, that the proper ornament retains the color of the wood. Thus on the smooth surface of the leaf of the door is shown by Fig. 1331, or with a regular subdivision of the framework, on its parts not covered by the hinges, or finally on the panels in the frame were placed geometrical or foliage patterns.

A greater area is obtained for painting by the use of double doors presenting a smooth surface inside, where either the wood itself serves as the ground or this was first formed of a coating. Thus the leaves of the doors of S. Elisabeth at Marburg were covered in the inside by parchment, on which were fastened the hinges and other fixtures, and on each panel enclosed by the bands was painted the imperial eagle.

By the use of such a covering it is advantageous to protect

the angles be overlaid and perforated strips of plate like the covers of books, and especially if the bands have openings, and under them is overlaid a fabric of different color, a further decoration is produced. Moreover by such overlays man pe obtained great magnificence also in secular buildings, that rises far above the existing luxury, that as a rule stops with wood staining.

For this the doors from upper Tübingen given in Heideloff (Note) afford evidence, which are covered by red velvet and overlaid by bands of gilded copper, beneath which is again placed green velvet visible through the openings.

Note. Mittelalterliche Ornament. Heft 7, plate 6.

IX. DEVELOPMENT OF ELEVATIONS OF TOWERS.

1. Treatment of Towers from Early Christian to the Gothic period.

Purpose of towers.

Towers occur as parts of churches since the 6 th and 7 th centuries numerously in both eastern and western countries. They were little added stair or watch towers, the latter usually isolated before the church. About the same time also extended the use of bells, that were hung on open frames beside the church or at proper places on or above it. If towers existed t that were suited to receive the bells, nothing was more natural than to place these in them. Where this was permissible, men adopted beforehand the form and width of the tower to this purpose, and sometimes also the building between two small stair towers was carried sufficiently high to afford a belfry at top. Gradually the safety of the bells increasing in number and weight evermore determined the erection of one or more principal towers. Besides simpler stair towers also retained their value, that w with the bell towers that together with the bell towers became the most prominent external characteristics of the House of God.

Detached towers. Added towers.

In Italy the bell towers usually remained separate from the church, while in northern lands they were organically connected with it. Aside from the earliest woodeu churches not remaining, only in certain countries (Bohemia, Silesia, East Friesland), did the use ofa detached tower receive anw consideration in the middle ages. The more difficult but laudable problem was placed before the architect by the combination of the design of the t towers with the House of God. According to this tendency, Romanesque and gothic art busied its endless creative powers again in astonishing abundance and diversity; one may well decide, t that no possibility of the solution of the tower has remained without trial. Especially arose a competition between the eastern ard western parts of the church, and this was not alone in the plan with double choir, but also with the plan developed expressly toward the east.

Towers of the eastern half.

At the east the crossing was emphasized by a structure flanked by two or four slender towers, which in combination with the t transverse aisle and the rich choir endings furnished a wonder-

wonderful perspective effect. At the other end rose the western structure according to its importance, accenting the entrance to the church, inviting admission by the call of the bells. Accordingly as the western facade or the crossing became predominant, or both remained in a certain equality, there became the greatest variety by the aid of the varied development of the different towers.

The tower over the crossing could rise square fhom the roofs in 2, 3 or more stories to an important height above the building, as on Great S. Martin at Cologne, S. George at Bocherville, S. Philipert at Tournus, the churches at Tours, Cluny, and on many English works, or it might be executed as an octagon, whether above the roof as at Königslutter, or already beneath the surface of the roof as on the Romanesque churches of the Rhine provinces, whose lofty crossing vaults also passed into the octagon in the interior. The cathedral at Toro in Spain has a two story sixteen-sided crossing tower with four attached side towers. Such with angle or stair towers starting from the middle structure also occur in other examples in the number of 1, 2 or 4, and on Great S. Martin at Cologne there still rise two stories of the crossing tower above the main cornice.

Far more common than the directly attached little towers are the bolder side towers standing beside the crossing, that either stand over the bays of the side aisles and east of the transverse aisle, as at Laach and Spires, or west of the crossing aisle as in Paulinzelle (but where the crossing tower is wanting). The combined occurrence of a crossing tower with four developed side towers is rare. The side towers are square, octagonal or circular (Worms), and are covered by wooden or masonry spires, while the crossing tower itself has a slender spire, and flatter hip roof (S. Apostles at Cologne), or is crowned by a dome. The side towers were soon extended higher and also the middle structure. If one then considers that also at the ends of the transverse aisle and beside or over the eastern end of the church occur single or pairs of towers or turrets, then the diversity of the forms of the towers of the eastern half leaves nothing further to be desired.

Towers of the western facade.

Almost as many changes occurred at the west facade, even if less in plan than in elevation. While the Italian basilica

uusally had a simple wall in front, before which at most was p placed a vestibule or a forecourt, German and French churches usually already at an early time exhibit a western high structure transversely, perhaps to be referred to the design of the double choir. In the simplest case the stairs are placed in the interior without external indication and are covered at top by a straight transverse roof.

Far more animated is the structure if it rises somewhat at t the middle (Fig. 1342, cathedral at Minden), whereby is obtained the first stage of the development of a "simple" middle tower, which rises at any increased height on the transverse building, either simply placed on it or organically prepared for beneath.

A different process of development is taken by the western b building, when stair towers are arranged at its sides (Fig. 1342 a). As soon as these rise higher, the germ is planted for the development of two western towers (Fig. 1343, Liebfrauen c church at Maestricht).

On the abbey church at Laach at the same time appears a middle tower placed on it and two attached round towers (Fig.1346). This richness is explained by this, that the double tower of t the church at Laach has retained for the front building rather the character of the transverse aisle (see Mayence). Elsewhere the three towers for the western structure described are rare, more frequently it occurs already, that the transverse building is connected with a high middle tower and to this are directly added side towers.(Thus in the cathedral at Paderborn, Fig.1347).

The single western tower naturally occurs in the small churches with single aisles, while the great churches with several aisles, city churches and especially the cathedrals with few exceptions (like Paderborn, Freiburg and Ulm) have received two western towers.

The two towers can extend up with the transvarse building in a single mass without a prominent vertical oh horizontal subdivision, as in many old buildings in lower Saxony (Fig. 1344, Neuwerk church at Goslar); or they stand on a cornice at the height of the eaves of the transverse structure, as on the parish church of Andernach, or finally already appear from below as an independent mass, whether by supporting vertical projections or buttresses, by a projection op the middle structure , (Jerichow), or by the projection of the fronts of the towers.

This separation of the towers from their intermediate building already occurs in the early time and toward the end of the Romanesque time creates greater value, until it attains a general predominance in the Gothic. Thus the intermediate structure can retain its transverse roof, that was particularly the case long in lower Saxony, or the gable of the middle aisle can appear on the west facade, as it shows itself quite early on Rhenish, south German, south French and Norman churches. As an example see Fig. 1345, church at Gebweiler.

Form of plan of western towers.

The form of plan of the old stone towers was generally round (S. Vitale at Ravenna, Aik-la-Chapelle), but circular bell towalso occur (Ravenna); round towers are frequently found on the Rhine in Germany, but as a rule the rectangular form is general for Romanesque towers, which rise above without change to the toop roof or to a square spire rising from the gables. It is worthy of consideration that the churches of lower Saxony already very early show a transition to the octagon, whether high a above as on the foundation church at Königslutter, or far below as on the cathedral at Brunswick and the Neuwerke church at Goslar (Fig. 1344).

A division into stories is usually not expressed on many Early Christian and Romanesque towers, but they rise from below to the top without belt cornices (Königslutter) and are animated by windows or openings for sound, whose dimensions increase upward. Also is frequently found an undivided extension to the height of the middle aisle, and from there a division in two or three more open stories. Finally there already occurs in the e early time, but more generally in the Late Romanesque division of art a division of the stories from below upward, where the number of stories usually lies between four and six (east towers at Bamberg, tower at Pisa; bell tower at Pomposa has even ten stories). Gothic cathedrals mostly return to 4 high stories of towers, which are connected with the church in a proper relation.

Towers in the Gothic period.

The division of the towers has generally become tolerably clear with the entrance of Gothic, the contest was decided in favor of the west facade, which received one or two high towers, and on the contrary the east end developed its magnificence in

a rich and charming grouping of the transverse aisle and the e ending of the choir, to which in great works was added a circle of decorative chapels. Thus the direction of the church from west to east was clearly expressed. Compared with the rich choir ending the importance of the crossing internally and externally didinished, and it therefore remained without special characterization or was satisfied with a small and slender roof turret. Larger Gothic towers over the intersection occur somewhat more commonly, aside from central churches, only in certain countries (England); Germany has but few examples to exhibit (church S. Katherine at Oppenheim, S. Thomas in Strasburg). On the whole the wealth in towers in the Gothic time issomewhat restricted, one or two principal towers dominate the building, other small crowning turrets or star towers only serving to animate the separate parts of the structure.

Where particular circumstances lead thereto, whether based on the locality or the internal organism of the building, men did not fear unsymmetrical forms of towers.

Generally the abundance of towers is an indication of the importance of the House of god; while the smaller churches of the orders according to the existing simplicity were usually contented with a roof or gable turret, and village churcher mostly received a plain western tower rising a little above the church, city churches and cathedrals competed in the grandest development of towers, which have come to us completed only in the smaller part, and mostly have been compelled to yield to the taste of later times, or have never been finished, since the high aims of the first builder were no longer understood by his successors.

2. Division of the towers into stories.

Relation to the church.

The connection of the towers with the church leads to a harmony or even to definite relations of the two. Since by organic development the horizontal divisions are carried out as nearly uniform as possible on all parts of the church, the position of the towers on the church has little influence in this respect, thus a tower placed before the middle aisle has substantially the same treatment in elevation as the double towers lying before the side aisles.

Number of stories.

On the basilicas the towers usually have four stories, the

first corresponding to the side aisles, and the succeeding one to the lofty middle aisle. The third story carries the tower above the height of the roof of the middle aisle, and the next l leaves all parts of the church below it and finally contains t the bells, forming the transition to the spire; for this reason it frequently changes to the octagonal form. Particularly clearly is expressed the division in four stories in the double towers at Rheims, Cologne, Strasburg, and in the single tower at Ulm. But the division into four, or if the spire is counted, into five parts in height is not absolutely fixed, there is also found a combination of two stories, as well as into several subordinate parts. Particularly common and with full justification is shown the height of the roof of the side aisle or of the triforium as a subordinate division of the second story, or as an independent smaller intermediate division, as at Amiens, Paris and Mantes (Fig. 939). Where the side aisle has galleries, its second division extends to the tower as at Limburg; similarly on the church of S. Elisabeth at Marburg the division of the side aisle is carried out, while in consequence of the hall form above is omitted one division, as generally on hall churches t the simpler division in height is also shown on the tower. The two upper stories of the tower were often combined into one, a and also indeed the fourth was suppressed in favor of a rich transition to the spire, as on the cathedral of Seez.

Heights of stories.

The heights of the stories can be entirely or approximately equal as at Ulm and Cologne, or they may gradually increase upward or conversely show a diminution upward. Beautiful is also an alternation of low and high parts, especially if thereby occurs an enhancement upward. Finally by a strong prominence of one story may be produced a happy effect (Marburg). All these solutions are represented by beautiful examples.

The two lowest stories.

The lowest story.

The interior of the lowest story of the tower, as indicated by the treatment of the plan, is either separated from the church and serves as a vestibule, or it belongs to the interior of it. In the first case all free sides of the tower are opened, or as in Freiberg only the western has an arched opening, the portal proper being found in the east side. But the angle piers

are always to be regarded as the essential supports of the entire tower.

Thh height of the vestibule is determined by the arrangement of a clearstory, by that of the side aisles, by aisles of equal height and galleries built over the side aisles, by the height of the gallery floor, or with two rows of windows, by that of the passage before the upper series of windows. The reasons therefore result from the requirement of communication with the triforiums on both sides, passages or galleries. Further must for the same reasons the heights of the two lower stories of the towers together equal that of the middle aisle.

Second story opened to the exterior.

If this concerns a middle tower, the second storw forms a vaulted hall, which is either included in the interior or is closed from the church, so that the west window abuts against the east wall of the tower and the other three walls are opened by cross arches. Then the hall is opened externally like a second vestibule and serves to admit light to the window in the aisle.

In the last case the floor of the upper hall will be constructed so that the water coming in through the arched openings shall not injure the lower vaults, and may be easily removed by means of gutters and spouts. We are unable to mention examples of this kind of towers over the middle aisle, but still this plan is found over certain French side aisles, certainly the grandest of all.

Second story open to the interior.

If the tower opens into the interior of the church, then a v vault will be formed below in it corresponding to the vault of a vestibule, which is entirely made open to the interior, or can be changed into a closed vestibule by later closed doors. The story above this forms a balcony open to the middle aisle, that recently is mostly occupied by the organ or the choir of singers.

Under the assumption of sufficient dimensions of the angle p piers, the window may occupy the entire width between them. Indeed by a reduction of its width to less than that of the openings of the doors may the stability be rather increased, since the overlying masses of wall increase the thrust of the arches of the doors.

Where a lesser width of the window is required, as this may

be partly by the simplicity of the entire design, partly may o occur by installing the organ in the second story of the tower, blind panels are then in place to reduce the upper mass of the wall, and they may be visible enternally or externally.

Combination of the lower stories in the interior.

When the need of such a gallery does not exist, particularly in small single aisled or hall churches, then may both stories be combined into a single free interior with the height of the middle aisle. The architectural system of the church, thus being with a clearstory, the triforium and upper windows, will then be carried around in the tower the same as in all other parts of the church. But there the continuation of the triforium in some cases may better be by an internal or external corbelling around the angle pier, then effected by an opening therein. Direct examples of the sort of mediaeval works we are unable to mention, yet there may appear for it the tolerably analogous case of the central tower of S. Maclou in Rouen (Fig. 1348), in which a passage arranged above the vaults of the middle aisle over the isdes of the square and within the thickness of the wall is arranged before the angle piers and a corbelling over the fourth part of an octagon in the plan. An application to the present case would be nearly given by the plan represented in Fig. 1349. This can be changed as in Fig. 1349 a, so that the passage from the triforium outward is on a corbelling a arranged above the vaults of the side aisle, and cut through the gable wall at c, and then either back through the tower wall to an inner triforium, or as Fig. 1349 a shows, it continues on t the outer side of the tower.

In any case also results an intermediate division from the c continuation of the triforium between the portal story and the clearstory, that naturally must assume a different form, according as the rear wall of the triforium or passage is placed inside or outside, opened by windows or closed. Further there results as on the gable walls, on the sill of the clearstory window a second passage supported by the lower one. But just as n noted for the gable on p. 419, the proportions of the heights may lead to an omission of the upper passage, and therefore an extension of the window openings to the sill of the lower one, thus leading to the same arrangement, that results from the division of the side aisles or side aisle walls in hall churches.

If that division fails in hall churches or single-aisled churches, then if it is not assumed in the tower, the upper window goes down to the gable, or there even occurs the arrangement in connection with the portal given on p. 556.

Combination of the lower stories on the exterior.

If we then transfer the portal and the windowof the middle a aisle to the eastern wall of the tower, then may result a vestibule of a height equal to thea of the middle aisle, that opens externally by arches of equal height. Such an arrangement is defective for different reasons. First the purpose of the covering of the vestibule by the disproportion of the height of the opening to the depth of the room in our climate is brought in question in the same way as in the antique columnar porticos arranged according to the usual rule, second the idea of the vestibule raised to the same height as the interior, third the effect of the other parts of the elevation as influenced by the height of these openings.

As already stated above, everything said heretofore also applies to the double towers placed before the side aisles.

The lower story in double towers.

If here the lower story in the tower usually has the same height as the side aisles and the height of the upper is determined by the height of the vault of the middle aisle, yet there is also formed sometimes ar in the cathedral of Noyon, the combination of both divisions in height made by the omission of t that intermediate vault, just as in the tower placed before the middle aisle. Hence these rooms in the tower in connection with the western bay of the middle aisle form a sort of western transverse aisle, that according to the ground areas of the towers either extends north and south before the fronts of the side aisles, or thus plays a part otherwise entirely similar to the actual transverse aisle.

The rooms in the towers thus open below toward the side aisles and above into the bay of the middle aisle lying between them by corresponding arched openings, the triforiums continue on t three sides of the towers, and stand in connection with another in the western gable wall, and likewise the three sides of aboveware opened by windows. From hall churches with two story side aisles or side aisle walls also result here the corresponding arrangement, thus either an intermediate vault or a simple pas-

passage. Yet as for the towers before the middle aisle there c can also here be built balconies in the towers, if then are wanting in the side aisles as in S. Elisabeth at Marburg.

The third story of the tower.

The succeeding story of the tower, thus the third if we pass over the division belonging to the triforium, first fulfils the purpose of raising the belfry above the roof of the church, so that the sound of the bells can spread at the sides, and thus forms the substructure of the belfry, accordingly usually containing the lower part of the bell cage.

Therefore the next determination of height results from the height of the roof, yet there is no direct urgency for it, and there are found examples with variations upward and downward. With only one western tower the church roof adjoins the eastern wall of this story, and for hall churches must also project into the next story, if it extends over the entire width of the nave.

Passages and external arcades.

This story is most subordinate of all and appears rather as an intermediate story between the lower part of the tower belonging to the aisles and the belfry. On simpler works it therefore exhibits only cosled walls scarcely opened by windows, which however may be made lighter by internal blind panels. The external recession of the face of the wall from that of the lower story, that results from the offset in the thickness of the wall, is most simply formed by a wash, but in larger dimensions may also serve for the arrangement of a passage connecting the roof galleries at both sides, and is furnished with a closed or opened balustrade, and thus provides a richer termination for the lower part of the tower. From this results a motive capable of very important and most varied treatment for development of the elevation. let us assume that above this story is arranged a second passage at the base of the belfry, which certainly can almost be required as an extension of the room occupied by the latter, and then the thickness of the wall scarcely permits another offset sufficing for this. Therefore occurs either a corbelling of the upper passage, or the utilizing of the lower recession for an arcade standing on its edge to support the upper floor slabs in the same manner, that in the aisles the passage found before the clearstory windows is borne by the arcade columns of the t triforium, or like the floor of the latter on the gable walls

of the transverse aisle on the arcade columns of the passage before the lower windows finds its bearing (p. 419), and constructions executed there are also employable here. Examples of this kind are presented by the cathedrals of Paris and the collegiate church in Mantes (Fig. 939).

With doupled towers the roof of the middle aisle can then extend to the front side, yet there the gutter between the towers must be farther inward, and therefore be placed higher than at the longer sides of the church. Since it is substantially narrowed py the vertical position of the wall of the tower, it would be better if set back still farther, and from this be arranged a short roof surface next the tower wall. Now since further the removal of the water toward the front through the arcade gallery extending before the west gable and connecting the towers presents some difficulties, this explains the termination of the church roof at the eastern face of the tower, and the arrangement of a terrace over the west bay of the middle aisle, as found on the cathedral of Paris, and which removes all those difficultie.

Blind recesses and blind arcades, arched openings.

The wall of the third story of the tower behind the enclosing arcades can be opened by windows, and again be animated effectively by blind arches serving to lessen the mass of the wall. On the cathedral of Paris are arranged on each side of the square of the tower two internal blind arcades, so that the structural system of the story concerned, besides the four angle piers, contains as many middle piers, that stand on the crowns of the arches of the lower windows. Two or more such blind recesses also in the lack of arcades could give the motive of the treatment for the tower story in question, as on the cathedrals of Laon and of Strasburg, on which the blind recesses are placed outside or even become actual arched openings

In the arrangement of blind recesses however, there must in all cases be a certain visible relation both to the openings of the story beneath as well as to that above, and we shall further return ho the investigation of the latter as well as to the possible preparation for the polygonal belfry.

The decorative effect of the passages and arcades around the roof story can be striven for in smaller dimensions, so that with the omission of the passages, the columns quite or nearly adjoin the face of the wall, and are connected to it by capitals

and bases and also by some headers, while the arches turned on them are bonded with the wall. Sometimes the latter also consist of certain slabs facing the wall, but which are made like tracery and are perforated like the scheme of tracery. Further are also common the little columns wrought in the bonded courses, and finally on later works are replaced by mullions without capitals continuing the simple tracery profile of the arches. As a tasteless echo are to be regarded those four angle pilasters connected by an arched frieze, which are commonly found on the simpler towers of the latest period, whose arches rest on corbels, if their moulding is not merely broken around above the lower horizontal division.

The two principal arrangements of the roof story, the arcades and openings of the arlhes essentially differ in their ground character, for the former produces rather a horizontal separation between the stories found above and below it, but on the contrary the latter represents a vertical connection of them in a vertical direction. The use of an arcade is moreover not restricted to the place mentioned here, but can also be arranged on other stories of the tower, and indeed even as a lattice before larger window openings in the wall behind.

The fourth story.

Openings for sound.

The fourth story of the tower contains the bells and is the most important of all, and this must be indicated as such externally by height and treatment; according to its purpose it forms a room covered in different ways, which permits the sound of the bells to pass out through wide and high arched openings.

On those simpler towers belonging to the smaller churches of rubble or brick construction, that are generally but sparingly opened, also the size of the openings for sound are smaller. In every case must here predominate either the mass of the wall as in Fig. 1350, or the size of the openings as in Fig. 1351. On the larger French towers with belfries of square form, as at Paris, Soissons and Mantes (Fig. 939), there are found at each side two tall arched openings. The advantages of this division in two parts sometimes found already on Romanesque towers are varied and important. If we assume here the horizontal termination of the given tower as originally intended, then the construction of the stone covering, that must be about as in Fig.

96, is made substantially lighter by the bisecting ribs turned between the middle piers. Likewise the depth of the jamb of th pier is far more favorable for the arrangement of the louvres, than the lesser depth of the middle pier required by a single arched opening. Further the desired character of the entire construction of the tower is enhanced by that vertical division, and the possibility of a lesser height is obtained from it, than would be required for a single arched opening filling the entire width. On other French towers, like those at Noyon and at Dormans in Champagne, are further found three arched openings at each side, that were also taken from the Romanesque.

Then for one, two or three openings, it is in the same manner to make the escape of sound as perfect as possible.

As already stated above, there is a certain relation between the arched openings of the different stories, and then is necessary a distinction of them from each other, according to their importance. The belfry is indicated even by those numerous free arched openings above the closed wall surfaces or arcades of t the lower stories, as shown in Fig. 939. But this effect is substantially weakened, if the lower story exhibits the same division in a competing manner. Therefore if the same division into two parts is usually assumed for both stories, the lower story must be distinguished from the upper by smaller height and lesser size of the openings, which is the case in many Romanesque and Early Gothic examples, or which is especially preferable in smaller proportions, there must be a combination of the triforium and window, analagous to that mentioned on p 407, about according to Fig. 1352. This is found also on the Freiberg tower, though in a changed condition.

Relation of the openings of the different stories.

But also a vertical division of the uppermost story by a free or attached arcade could be made, or even by mere blind arches, with the assumption that this is not already found in the same manner in the story beneath. Generally the superposition of different arrangements, yet suited to and in a sense requiring each other, produces a characteristic motive of Gothic tower construction, opposed to the not rare and quite too similar repetition on Romanesque towers in Germany and Italy, that is injurious to good effect, as it is contrary to the nature of the matter.

While the heights of the other stories in a sense are determined by the different divisions of the height of the church, s such a limitation vanishes from the belfry. In the simple buildings with great closed wall surfaces, that predominate in Germany at least in the country, the height varies from about the half diagonal of the external square of the plan to its rarely exceeded side. More slender proportions up to twice the side are found only on richer works, and already belong rather to an expressed pier construction.

Variations from the given division of stories.

Every heretofore assumed division of the tower into four stories must not be too strictly taken, as it lies in the nature of the matter and in the conception of artistic freedom, but as already mentioned at the beginning of this Chapter it may suffer many changes, yet where must always remain the suitability of the church. We have already mentioned the combination of the portal story with the window story resulting from the hall church, and have given in Fig. 1352 an example for an at least formal combination of the two upper stories, which according to t the conditions can be extended to an actual one. Further by simpler construction and smaller proportions the entire tower would remain undivided up to beneath the belfry, and the latter could even be placed in the spire, as will be shown later.

An increase in the divisions in height is already contained in the mentioned carrying of the triforium around in the tower walls, and is even enhanced on the towers of Amiens, since above the triforium is found a second lower arcade balustrade, in which the intervals between the columns are filled by figures, whose heights form the difference between the heights of the clearstory windowsin the nave and that of the western base window.

But also the fully justified equal division results from the arrangement of vaulted galleries over the side aisles, as on the towers of Mantes (Fig. 939), and it would be here the connected arrangement of the triforium lacking in Mantes, that would increase by one the number of divisions by carrying it around the tower.

Further subordinate divisions are also found on the higher s stories as in Freiberg, where the proper belfry is contained in such a subordinate division of the uppermost story of the tower, an arrangement to which we shall later return.

Upper termination of the towers.

Towers without spires.

The most common termination of a tower is a pyramidal spire (p. 580), but the simplest is a horizontal ending, thus the covering of the belfry by a terrace, which is most naturally formed by a layer of stone slabs, but is replaced on the cathedral of Paris by a low hip roof covered by lead with a passage extending around this. In every case there results for flat roofed towers a tracery balustrade above a more or less richly formed but bold roof cornice. To secure that balustrade pinnacles are then usually set at regular distancer (Fig. 939), which at the same time animate the horizontal termination. The same effect is then obtained in a higher degree by the endings of the buttresses, or most perfectly by the arrangement of angle turrets.

Stair towers on them.

The latter are required by the necessity for stairs leading to the upper terrace. But thereby results a substantial difference, according to the different positions of the towers. Thus a tower placed before the middle aisle with the assumption of a horizontal termination, at least two such corner towers, and indeed the second are required for esthetic reasons, since thereby the effect of the gable facade is calculated for the culmination in the high architecture at the middle, which effect would necessarily be injured by the one-sided height of one corner. On the other hand the effect of a central tower with a horizontal termination in which culminates thus the entire church building at the sides, which would be disturbed by every departure from the concentric symmetry, and hence four corner towers are required here.

For double towers the need of a symmetrical treatment vanishes, since these do not express an architectural independence for themselves, but first in combination with the entire gable facade, they can be content with a stair tower for each at the inside or outside corner, and generally suffer departures from symmetry in details. Thus we see the towers of Mantes (Fig. 939) treated almost symmetrically up to the story corresponding to the clearstory of the church. But above the latter the symmetry is so far annulled by the turrets on the outside corner piers and the arcades surrounding them, that the middle pier of the double openings for sound in the belfry are moved to the middle

line of the lower window or the entire side of the tower.

Comparison of towers with and without spires.

The termination that results from a horizontal covering of t the towers is always stronger, so that it usually seems doubtful, whether according to the original plans a pyramidal roof was intended for towers now covered by terraces. But the contrary is here expressed first by the great number of those, that in any case must allow it to appear as a singular accident, that all should be completed directly to the placing of the spire, as well as the fact, that this form of tower is restricted to France, Belgium and England, and was never produced by the same conditions in Germany. But the most important reason for the originality of the form is, that on all towers of greater importance and finer execution, the reception of the spire is prepared for by the entire form of the belfry in a way so that both parts require each other. But such preparation in the ground form of the belfry does not fail alone in the towers in question, but the placing of the spire is even substantially made more difficult by those variations from the symmetrical design as thus at Mantes, but are found more decidedly on the towers of S. Gudule in Brussels, whereby the middle line of the vertical part of the wall differs from that necessarily belonging to the entire tower, and thus over the middle of the ground square, or yet the ground form of the spire set on the belfry fall entirely s separate, thus making any organic connection impossible. Perhaps in the no small number of towers in Normandy with which are to be counted certain in England, on which a spire is unsymmetrically placed, rather the latter must appear as subsequent by the ornamentation produced by the amgnificence of other French towers.

3. Basal forms of spires and transitions to them.

Spires of round and polygonal towers.

Conical and domical roofs.

Round towers almost without exception have round roofs, and these may have the form of cones, low or steep domes or also t that of a spire with concave sides. As exceptions are to be mentioned the side towers of the abbey church at Laach, that with the circular form have received octagonal spires; the transition to the octagon is made in the arched frieze of the main cornice.

Pyramidal spires.

Polygonal towers seldom exhibit a polygonal dome (like the c

churches of Bari and Lecce), but more commonly a round one like Notre Dame at Avignon, S. Honorat at Arles, etc., but generally pyramidal spires with the number of sides of the tower. The latter also frequently occur as stone roofs as those of wooden construction, those covered with metal, slate or tiles; their effect depends very much on the inclination of their sides (Figs. 1353, 1354). In Romanesque times also occur both low hip roofs with height less than width, and that are particularly suitable for wider towers, as well as also spires with pronounced tendency in height, but which usually do not exceed the proportion in height of 2 to 1. Gothic spires become more slender; a height exceeding 4 times the width can pass as an average value, and this is found tolerably exact on the towers of Cologne, Ulg and S. Denis. Somewhat lower are the spires at Chartres, Freiburg (3 3/4), but on the contrary more slender are those at Seez and Marburg. A proportion of 5 : 1 is indeed rare, yet certain old and new towers also notably exceed this, especially the ornamental roof turrets, the spire of the cathrdral of S. Stephen at Vienna evey received the inclination lying between 6 and 7 :1.

The pyramid can extend to the outer edge of the wall of the tower or be set back somewhat from it, when the recession is c covered by a lower inclination (Fig. 1355), is concave (Fig. 1355 a), or has a horizontal passage (Fig. 1355 b). All eight sides may receive gables (Fig. 13565 as examples may be mentioned the crossing towers at Sinzig and Limburg); if the four principal sides are to be accented, these may alone be ornamented by gables, also if they are wider than the other sides . (Fig. 1357, S. Eusebe at Auxerre). An entirely different form of spire is found py rotating the pyramid 22 1/2°, so that its angles then appear at the apex of the gable,Fig. 1358, crossing tower at Bonn.

Star-shaped plan of spire.

If the line of junction of the surfaces of the spire coincides with the vertex of the gable (Fig. 1358) or is to be parallel to it (Fig. 1358 .), then the height of the spire depends on the height of the gable, and it must be about 6 4/5 times the height of the gable measured in the plane of junction. (h in Fig. 1358 a). With the inclination for the gable of 45° there results from this a height of the spire that amounts to about 1 1/2 times its width, but for 60° to about 2 1/2 times the width. A steeper spire

either leads to a horizontal break in the line a b (Fig. 1358 a) or gives opportunity for a recession downward of the junction line a c (Fig. 1358 c) from the apex of the gable, the latter solution with the lower spire is not very satisfactory, the first one with an angle above the apex of the gable is just ugly and allows the spire to appear stunted. To avoid both, probably men came to the peculiar Romanesque form of spire with alternating hips and valleys represented in Fig. 1359, which is generally found on the Rhine (S. Apostles at Cologne), both for octagonal and square towers, and it is even transferred to the choir polygon (Münstermayfeld). Such roofs are built of wood without difficulty, but for stone the valleys must be strengthened, or still better be supported by steep arches placed beneath them. The valley may also be replaced by a flat rounding.

Spires of square towers.

Gable or hip roofs.

A rectangular tower can be covered by a gable oh hip roof with or without a ridge turret, but this particularly suitable covering for rectangular plans is rather restricted to secular buildings, aside from the oldest towers and later village churches. The most natural and simplest covering is also afforded here by the pyramidal roof (Fig. 1360), it can be made octagonal or curved at the base (Fig. 1355); on the other hand the Romanesque rectangular stone spire sometimes is swelled with great advantage for static reasons (Fig. 1361), which by a greater curvature passes into the square hipped dome, Fig. 1362, monastery church near Zambek (See Kunstdenkmäler der Österreiches Kaiserstattes).

Above the four sides the spire may again be placed gables; if at the same time the spire be rotated 45°, so that its hips meet the apexes of the four gables, there result the very common forms of Romanesque terminations of towers represented in Figs. 1363, 1364 (Halberstadt, Limburg, Laach, Coblenz, Maestricht, etc.). The height of the spire in the regular construction amounts to twice the height of the gable, and the four sides of t the spire are regular lozenges. Variations of the relations of inclination between spire and gable are made as for octagonal towers, Figs. 1358 to 1358 c.

Other forms of roof.

Also folded roofs (Fig. 1365) can occur over the skuare. To the last are closely allied intersections of gable roofs (Fig.

1366), as such are found at Paderborn (Fig. 1347) and on the market church at Hanover, in the last example having an almost necessary roof turret at the middle.

Figs. 1364 to 1367 are nearly allied in spite of their apparent diversity, since they all result because straight lines (rafters) extend from the base points c and apexes a and b of the gables to the apex of the spire. If the height of the spire be twice as great as the height of the gable there results Fig. 1364, but if it is 1 : 2 times as high then occurs Fig. 1365, but if they are equal then is produced the valley roof in Fig. 1366, and if the spire is more than twice the height of the gable, there finally results an octagonal pyramid, Fig. 1367. (On its angles at the edges and slenderness, see p. 584 below).

As an exceptional form may be mentioned the folded roof over the twin gables of S. Gereon at Cologne (Fig. 1368).

The last examples (Figs. 1365 to 1368) exhibit changes from the square to richer ground forms of roofs, so that we have thereby come to a Chapter which occupies a particularly prominent place in the history of the development of tower construction. Rectangular spires present structural differences in construction in stone (see below) and besides by changing the point of sight it makes a greatly varying outline not equally favorable from all sides, which is easiln explained, when one remembers that a square seen diagonally is 1.414 times as wide as the side, thus a spire when viewed in front has the proportion of 4 : 1, but only shows diagonally that of 2.8 : 1. But since the masters in the middle ages more than those of any other time d designed no flat architecture (the So-called facades) but masses of building occupying space, they were extremely refined in feeling on this point. Therefore they transformed at least the roof and very frequently the entire upper portion of the square tower into a more central form; sometimes the circular plan occurs in the form of domes and cones, more commonly the polygon and especially the octagon, which is developed most naturally from the square.

Octagonal spires on square towers.

If the square has the defect, as we have seen above, of becoming considerably wider in the diagonal view, this vanishes almost entirely for the octagon, for its diagonal is only 1.082 times as great as its least width, or in other words the diagonal

view is in proportion to the geometrical about as 13 : 12 (instead of 14 : 10 as for the square). A spire that shows a height in the proportion of 4 : 1 in front view cannot appear less than 3.7 to 1 when seen diagonally.

Consequently if on a square there be placed an octagonal spire, the spire is helped as such, but more prominently appears another defect in the diagonal view. for just as the spire in this view shows the least width, but the tower beneath it exhibits its greatest breadth, the direct transition between the two at the angle looks very ugly to the eye (Fig. 1369). If then were reduced somewhat to favor a passage and thus the balustrade of the latter conceals the lower part, the ugly effect would be considerably increased, especially when seen from below.

A good adjustment of both is thus an indisputable requirement, that can be satisfactory in various ways. First in the spire itself can be completed a transition from the square to the octagon, and then intermediate structures can be erected on the free angles, and further an intermediate member may appear between tower and spire, and finally the transition may find its place high above or farther below in the tower itself. All these solutions have been expressed in manifold styles, the most important of which may be briefly stated.

Transition from the square spire to the octagonal one by chamfering.

A transition in the spire itself in the mode of Fig. 1370 and of the corresponding diagonal view in Fig. 1370 a is simplest, if it commences square below, is chamfered at the angles by four oblique planes, so that at the certain height it forms a regular octagon and then continues as an octagonal pyramid. The four angle surfaces have a slight break at the lines a b and c d, w while the four other sides extend in a plane. If the transition in the diagonal view be gradual, then the height e a of the chamfer must not be too little, but should be at least 1/2 or 2/3 of the bottom width of the spire. Frequent mistakes in this respect are ma e in new towers, so that the transitions are not usually perceived from a low point of sight.

If this transition be made on a spire that has a low inclination below, there results a break in all the eight sides of the spire, Figs. 1371, 1371 a. Aside from the fact that a slight reauction is sometimes justified by a lessening of the thrust, the

effect of the earlier tower does not appear favorable. The transition becomes in the diagonal view again very abrupt, and the height of the spire is thereby reduced unnecessarily. But a high spire particularly contributes to an imposing and beautiful effect of the tower, and besides also for financial reasons the finally determined height of the tower is more advantageously attained by a high spire than by high walls. Yet in later times in the wooden spires of many village churches and secular buildings, the base of the spire has been reduced as much as possible by the use of a flat or curved plinth, but thereby the slenderness of the pyramid is increased. (Fig. 1372). On small ornamental structures such spires are indeed justified, but in any case with the skill by which they are designed, one cannot refuse t them the merit of a certain decision in contrast to many flat new attempts.

Transition by four gables.

The transition from the tower to the spire is facilitated by the existence of four gables over the sides of the tower. A form already approximating this is shown by Fig. 1373. It may be conceived to originate either by supporting the angles of the pyramid in Fig. 1364 or by the ordinary placing of an octagonal pyramid on a square tower by extending downward four pyramidal sides to cut off the corners of the tower. Figs. 1373 a and 1373 b show sections through the sides and the diagonal. If the completed upward, they either rise free from the surface of the spire, as at the left side of Fig. 1374, or its sides intersect like a roof, as in Fig. 1374, at the right. If no break at the height c c is to occur, then the height of the spire is dependent on the height of the gable, and it results from making it twice the height of the gable. If the spire is to be more slender, there occurs a break in the line c c, or the line of junction bends back (Fig. 1374 b). On this see Figs. 1358 a to 1358 c. In the diagonal view such towers of similar outline are as drawn in Fig. 1370 a.

If the transition is to be more continuous, then can the finials or added buttresses shown at the angles in Fig. 1375 or s some other properly formed be placed on the angles to load them with advaytage. The ashlars of the gable cornice assume the rather complicated forms seen in Figs. 1375 b and c. If the apex of the gable projects like a window gable (Fig. 1375 d), then

the ashlar will also receive a corresponding form.

When the base of the spire is reduced, the four gable roofs will project farther, until they finally approach two crossed gables (Fig. 1366) in their effect with a central spire.

Diagonal position of the spire.

By placing the spire diagonally so that four edges stand on the apexes of the gables and the other four on the angles of t the tower, a particularly pleasing general transition is produced in both front and oblique views (Figs. 1377, 1377 a), that is already much found on Romanesque towers. If the line of junction falls on the side of the gable or a parallel to it, then the spire from the lowest point to the highest apex is 3.1414 times as high as the gable. With an inclination of the gable at 45° the height of the spire becomes 1.707 times the side of the square or 1.21 times the diagonal of the square at the bottom a a, but with an inclination of the gable at 60°, it becomes 2.96 times the lower width a a or 2.09 times its diagonal.

If the spire is to be made steeper or flatter, there will occur a break in the line c c, or the line of junction will no l longer be parallel to the edge of the gable. Finally sometimes occurs the following expedient, to vary from the regular octagon, so that at the height c c of the plan of the spire so that the left side of Fig. 1376 corresponds to it, but the right side to a flatter spire. The last variation appears on the towers at Spires and exists on the western building of S. Apostles at Cologne. It is to be noted on this occasion that also above rectangular towers can be erected similar spires with corresponding irregularities. If the spire ever becomes flatter, then finally the point p (Fig. 1376) will fall in the line m n, and consquentlly from the octagonal spire results the square spire of Fig. 1364, and a further depression of the apex of the spire and a connection of it with the corresponding corner points would finally lead to the folded spire with the star-shaped plan m p'n. (Figs. 1376, 1365). To animate and load the corners also on these towers may again be placed finials or turrets between the gables, that are based on the walls of the tower or partly on the angle buttresses. But the angle turrets are preferably restricted to the width of the gable, and S. Patroclus at Soest presents a very old example of this. The gables were decorated by arched openings, polyfoils, blind arches or tracery, and some-

sometimes the openings for sound in the story of the tower extend into the gables.

Here is also mentioned the peculiar spire of Treysa (Fig. 1410), that has smaller oblique gables between the four principal gables, whose apexes likewise receive the hips of the spire.

Detached angle pyramids.

When the octagonal pyramid rests directly on the square tower horizontally without gables, then there remain free four triangles at the corners (Fig. 1378), and the result of this is the ugly diagonal view, p. 582 and Fig. 1369. If then the covering spires of Figs. 1370 to 1372 are not employed, then to improve the outline and remove water, thin angles must have separate coverings, which are to be harmonized by bold heights with the slenderness of the spire. (The roofing of the tower may be compared with the roofing of a hall church of three aisles, that either has a common roof as a great middle roof with different adjoining side roofs). The triangles may first have angle spires similar to the main spire, which take the form of triangular pyramids. The vertexes of the pyramids may lie over the external corners (e in Fig. 1378), see Figs 1379 and 1380 from the church in Gebweiler, they may fall above the centre of the triangle as at the left in Fig. 1381, or be moved over the middle d of the side of the triangle as in Figs. 1378 and 1381 at right. Fig. 1381 a shows the two last cases in diagonal view, between the main spire and the side spire is formed a sharp line with a little gutter below, best avoided by inserting a little gable roof, as indicated by the dotted line. More simply may be avoided the deep cut by increasing the triangular pyramid to a square pyramid by adding a symmetrical half, which stands over e f g; in Fig. 1378 its rear edge intersecting the surface of the spire at k, as it shows in the diagonal view of Fig. 1382 and a more tasteful effect; the geometrical elevation remains the same. T The effect of such an octagonal spire surrounded by four little angle pyramids, that is found on many German and French towers in stone and wood, is particularly imposing and interesting on account of its simplicityand clearness. Fig. 1384 shows an example of a little subordinate spire of Freiberg minster, that is steeper than the principal spire, but more commonly both have the same inclination.

Attached angle pyramids.

An entirely different result in both views, if the angle pyramid of the form of either Fig. 1381 left or right is connected by a gable roof with the side of the spire rising behind it, as in Figs. 1383, 1383 a left; it appears already as a part belonging to the principal spire, which is more the case if the points is placed nearer the side of the spire, into which it may finally pass, Figs. 1383, 1383 a right. Thereby is attained the simplest covering of the corner, it may be steeper or flatter as on nmmerous towers of the early and late times, and approximate in effect again to the common spire of Fig. 1370.

Transition to the octagonal spire by an intermediate piece.

Passage at base of spire.

Although we have seen that it is well possible to properly arrange the square tower with the octagonal pyramid resting thereon, yet this aim can be attained even better, if the transition is already made below the base of the spire (as examples see Fig. 1396 and the right side of the tower at Gebweiler, Fig. 1345). This is attained by a corresponding form of the upper p part of the last story of the tower (belfry), but there can be a small intermediate division rising above the belfry, like a plinth of the spire, and which is especially added if a balustrade exists. As already stated, by recessing the sides of the spire it is next to utilize the space between the sides of the spire and of the tower for the arrangement of an exteroal passage at the base of the spire, which is enclosed by a tracery balustrade,whose angles can be secured by pinnacles, giving a rich ornament to the entire tower.

Since then a greater value is justly placed on the arrangement of such a passage at the considerable height permitting a wider view of the people, we shall here state, that this is possible even with the spire not set back, when the floor slabs of the passage are borne by an arcade standing on the lower part of t the full spire (Fig. 1386). The transition of the square to the octagon beneath the passage remains visible through the arcade.

Interposed sjuare intermediate story.

But a good transition with the recession of the spire and the arrangement of the passage is even more required than otherwise, and it can be placed directly above the passage according to one of the solutions in Figs. 1370 to 1377, or as stated, in a very

effective manner is raised above it by a low story recessed by the width of the passage (Fig. 1385), but otherwise formed according to ann system there described.

If then the loading of the angle pier by a turret is to be t termed structurally favorable, this will in the last case afford the further utility of strengthening the walls of the story inserted, and of brigirg it into closer connection with the belfry. Likewise will angle turrets almost necessarily produce a beautiful transition on account of the horizontal division caused by the passage.

Both aims will be attained in more complete measure by pinnacles corresponding about to the thickness of the wall or even exceeding it. These may partly stand on the buttresses, if the latter extend the full height of the belfry.

The southern of the Marburg towers has square and the northern octagonal pinnacles. The square ones (Fig. 1389) have the width of the buttresses and with them project somewhat from the face of the wall, the octagonal ones being wider than the buttresses (Fig. 1389 a), so that the outer side lying on the diagonal is corbelled out over the angle between the two buttresses. The r rear angle of the pinnacles coincides with the angle of the recessed story, except that below is an opening to provide a passage (Figs. 1389, 1389 a).

A similar but simpler arrangement with buttresses extending higher os shown by the tower of the Frankenberg church, on which indeed instead of the originally intended stone spire was m merely erected a temporary roof, so that we must restore in Figs. 1387 and 1387 a the added spire as well as the ends of the buttresses.

On later works the dimensions of the pinnacles placed either on the buttresses or the angles of the walls are frequently reduced, so that they stand entirely free before the walls of that recessed story, and therefore are without structural importance for it.

Yet a connection is sometimes arranged, which is rather merely for the security of the more ornamental pinnacles, than for the angles of the wall, and consists of arches or flying buttresses turned diagonally, or is made by channels for water passing through the pinnacles. Examples of this kind are indeed shown in a changed form by the towers of Wildungen (Fig. 1388) and of

Volkmarsen. However the effect of this arrangement is still very picturesque, even if it does not bear comparison with the older examples.

Octagonal intermediate story.

The necessity for this transition from the square to the octagon can be avoided if the upper recessed story be made octagonal. However the effect is not favorable, especially in the diagonal view, since the angles of the square tower form an excessive p projection, and when seen from below conceal a great part of the upper story (Fig. 1391). In any case this design requires longer angle pinnacles, and if a connection of these with the angles of the octagon becomes preferable, about as in Fig. 1390.

One should not fail to indicate, that an optical illusion aids the unpleasing effect. For physiolical and psychological reasons not to be explained here, acute angles generally seem to us less acute and obtuse angles less obtuse, than they really are, which has the result that the tower in Fig. 1391 appears to have the outline in Fig. 1391 a, i.e., both the tower and the intermediate story appear to widen upward. The inclination of the walls and even the inclined positions of the columns on German towers must in part be based on similar phenomena; besides the almost constantly employed battering of the walls upward or recession in offsets, the middle ages had an effective means in the buttresses strongly enlarged downward. In the particular case occurring here, also much can be accomplished by angle pinnacles or other transitions at the points in question.

Defects of an intermediate story above the passage.

If the intermediate story be very low or be entirely wanting, there appears in the diagonal view the effect shown in Fig. 1369, but still more increased, since already the tower spire is reduced at each side by the width of the passage. Therefore this solution is to be termed less favorable, yet where it came into use, it required the more skilful treatment. As an example may be mentioned the tower of the Teyn church at Prague.

Here the transition is made by four octagonal angle turrets with pointed spires set on the angles of the belfry and strongly corbelled out, that are connected with the great spire by protecting roofs placed diagonally. If then also the entire tower more nearly approaches a secular character by that great projection of the angle turrets with the passage, yet just this arrangemen

is in the finest harmony with that represented in Fig. 1472, a and further the turrets corbelled out above on the spire, and this arouses the most vivid surprise, that the master understood how to produce such a picturesque effect on the basis of an unfavorable motive by the consistency of the development.

Angle turrets at the height of the base of the spire.

The effect of an intermediate part inserted between tower and spire is thereby attained, even if only apparently, so that the angle pyramids represented in Fig. 1382 are raised above the b base of the tower by a plinth with vertical sides or an arcade, thus being made an actual turret (Fig. 1392). These may also a appear in direct connection with the buttresses, if two of its angle piers stand on them as shown in Fig. 1393, so that a diagonal square results for the angle turrets . Then the buttresses either terminate in the returned cornice of the belfry or below them by a slant, the latter being placed on the angle pier below the cornice of the belfry.

Then there results for these angle turrets the ground form of the octagon, if they rest with two piers on each buttress (Fig. 1393 a), so that thus the width of the buttress agrees with a side of the octagon. The angle left between the buttresses may then be filled by corbelling as shown in Fig. 1394, so that it forms an enlargement of the octagon. This transition then resultus more readily, if as in Fig. 1393 a the buttresses are removed from the angles of the square, so that the latter forms a single or double offset between them.

Such a design is found on certain French towers, but were intended on others like Noyon and Soissons, as may be recognized with certainty, and on that last named at least in the form of little angle balconies projecting from the terminal terrace and carried a few steps above their floors as constructed.

The interiors of such open angle turrets receive a horizontal floor, from which the water is removed by spouts, and made accessible by doorways opened in the diagonal walls of the spire. According to the ground form of the whole there may still remain small horizontal surfaces between these little angle turrets, affording for the arrangement of gargoyles beneath the angles of the spire.

With these angle turrets may again be combined passages at the base of the spire, that lead through the angle turrets, or extend

around them on corbelling. The last arrangement is found on a tower at Louvain belonging to the late time of Gothic, in the manner that the closed angle turrets are placed on the buttresses, and the passage is corbelled out around them. The perforated spire with tracery begins behind with a square base, but changes into the octagon directly from the floor of the passage by a transition formed according to Fig. 1370.

Dormer windows on the four sides.

On French towers the effect produced by the angle turrets is usually only enhanced by this, that on the sides of the spire parallel to the square are built dormers likewise at the height of the base, but of such slender proportions, that they form a crown with the angle turrets, from which rises the spire of the tower in a very stately manner. These dormers are then either terminated by spires, as a rule rectangular, or by pointed gables, that however stand free, so that their rear surface is either a vertical surface or a steep hip. In both cases a gutter lies between it and the spire (Fig. 1392).

Angle turrets on wooden spires.

On many simpler towers without buttresses, and as a rule on those with wooden spires, the angle turrets are partly corbelled out, and then and then either built of masonry as on the tower of S. Peter in Lübeck, or constructed of wood like the spire as on a great number of village churches in Hesse. There the floor of the spire is utilized by the projection of certain beams or tiebeams for corbelling; the angle turrets themselves a are made octagonal or still more frequently are hexagonal, opened by a doorway to the spire and by small dormers on the free sides, and covered by slates like the spire (Fig. 1395).

The same motive of corbelling by projecting ends of beams is sometimes employed in smalles dimensions also for making the transition from the square tower to the polygonal spire. (Fig. 1475).

Transition of the upper part of the tower (belfry) to the octagon.

The transition from the square tower to the octagonal spire is made considerably easier, if it can be completed in the tower, so that the upper part and particularly the belfry is already octagonal, but it is only possible when sufficient space r remains for the hanging and the movement of the bells.

Internal transition to the octagon, corbelling above.

As an intermediate stage between the square and polygonal belfry may be those arrangements, in whilh is either found over t the belfry a low and recessed octagonal story (Figs. 1387, 1388), or the transition to the octagon is below the base of the spire in the mode of Fig. 1396, or is similarly effected. In both cases the walls of the sides falling in a diagonal direction partly stard over vacancies, as indeed the case in like manner for the walls of the spire, but here by a continuation of the inclination of the spire inside to the square, it may be most easily attained (Fig. 1413). The vertical walls of the octagon in a d diagonal direction, that according to their height exert a greater pressure downward, in the same manner may be placed on steep corbellings, and as a rule are however supported by spherical or conical surfaces (Figs. 1397 to 1399) or by arches (Figs. 1400 to 1402).

The latter consist of two or more concentric courses, which are turned between the internal faces of the walls of the belfry and are either corbelled out with their square springings or rest on a projection of the wall. Figs. 1400 and 1400 a show the latter arrangement from the towers of the Liebfrauen church in Worms. These arches thus transfer the load partly sidewise to the walls of the belfry, but partly to one another and thus finally to the angle. On Freiberg tower is found a similar arrangement, except that the separate courses of the arch do not join by horizontal but by inclined bed joints with each other, and thus approximate the form of half domes or of domical segments (Fig. 1405).

Fig. 1401 exhibits the corbelling in the cathedral tower at Paderborn (after a communication from Building Councillor Güldenpfennig there). The arches there partly rest on a projection from the wall, partly spring obliquely from the wall. With round or pointed arches the parts of the arches projecting from the face of the wall could be supported by corbels or little columns. Fig. 1402 shows both, and also in the lower part is a very frequently occurring corbelling like a pendentive. Especially varied transitions are shown by the higher dormers in the crossing towers of Rhenish and French Romanesque buildings, from which are also taken Figs. 1397 to 1399.

Internally octagonal and square belfries.

By extending these transition vaults beneath the floor of the belfry there results for it then the octagonal ground form, which however is unfavorable for arranging the bell cage and may limit the space possibly required for swinging the bells. Therefore on certain French towers as at Chartres and Rheims, the octagonal belfry is henceforth connected with the angle turrets standing at the height of the floor, and here forming the transition to the square; by means of the arched openings that are in the sides of the octagon lying diagonally, so that at least for the interior of the belfry the square plan is again obtained (Fig. 1394 a).

Form of the angle turrets.

Each angle turret then stands at the height of the floor of the belfry directly on the buttress, as elsewhere at the height of the base of the spire, and is capable of the most varied forms. What first concerns the height, it can have the same height as the belfry (Fig. 1394), thus being surrounded by its cornices in Rheims and Laon, and above these being directly crowned by spires, which arrangement was at least intended in the works mentioned. Instead of these low stories could still be placed above the cornice to support the spire, or finally the angle turrets could be lower than the belfry, so that there as pinnacles may adjoin its walls in part or for their entire height, as in Senlis and Chartres.

They can further for their entire height be formed of continuous little columns connected by arches is in Rheims, or be separated into two stories by a floor as in Laon and the cathedral of Naumburg. These stories may have the same ground form as in Naumburg, or differ from each other as in Laon, where on the lower one formed as a square set diagonally rests the upper one composed of five sides of an octagon, whereby however the upper story is not accessible, and therefore its floor is beset by c colossal animals looking outward between the little columns.

Stair towers.

One of the angle towers can enclose a stair tower leading to the height of the base of the spire, either so that it has its separate walls or piers, within which the pier of the angle tower stands as in a cage as in Rheims and Senlis, or so that the steps and strings are borne directly by the piers of the angle tower, as on some later works to which we shall return later.

It is here allowable for the stair tower to replace the angle tower at one corner, and by its different form make a change f from the symmetry.

If we have designated the angle tower above as usable for the arrangement of an internally square belfry, this use has not always been made of it, and in Laon and Senlis only the diagonal sides of the octagon open to the angle tower by doorways, so that by the little towers besides the obtaining of covered porches is received only the utility of loading the angles.

Tower at Freiberg.

On the tower of Freiberg minster is found a peculiarly spirited change in the motive of the angle turrets corresponding to all requirements in the most beautiful way, into which we must enter more fully.

As already stated, the purpose of the little towers is manifold, they serve to establish the square ground form of the interior, to load the corners and at the same time to form the transition from the square to the octagon. Accordingly in Freiburg the belfry rests on the square of the tower according to the ground form given in the lower half of Fig. 1404, i.e., it is internally square and on the exterior is made the transition from the square to the closed angle turrets formed with equilateral triangles (Fig. 1403). The latter rise as accessible space to nearly the full height of the belfry, thus retaining of the square plan in the interior so far of value, and it terminates inside by the before mentioned angle vault supporting the diagonal sides of the octagon, Fig. 1405, which represents the interior of the belfry in diagonal view, makes this arrangement evident, which was already given in Fig. 96, but the posts supporting the ceiling of stone slabs above the ribs are not drawn.

Above the belfry is then found a high octagonal hall crowned by the tracery spire, opened by eight great arched windows on all sides divided by mullions, whose plan is represented by a b c in Fig. 1404.

At the height of the latter the angle turrets have only the purpose of loading the angle piers, and accordingly exist in t the well known tabernacle form, whose terminal finial rises above the base of the spire.

The effect of the additions like tabernacles is thus heightened, in that they project beyond the arched openings found in

the diagonal sides of the octagon. These are also properly to be regarded as the spires of thesetriangular angle turrets, whose chosed sides are decorated by mullions and tracery, and form a very happy connection of the simple lower story of the tower and the rich and airy forms of the octagonal hall and of the spire. This combination is thereby closer, since the ground form of the belfry and thus the octagon with the four triangles adjoining the diagonal sides extend down also a short distance into the tower square, and ther first pass by washes into the full square, so that the buttresses of the latter with their caps extend to the sides of those tr angular walls, and with the wide projection that runs around on the base of the belfry, enhances the sharp impression of the separate stories by the balustrade supported by corbels, yet without disturbing in the least the intimate relation of all parts to each other.

If we now collect together the peculiarities distinguishing the Freiberg tower from the previously mentioned French examples, we have the angle turrets enclosed by walls instead of being open, a tabernacle form crowning them instead of the simple spire, instead of the belfry directly covered by a spire on French towers is a hall placed thereon, and as an addition the passages at the base of the belfry and of the spire.

These passages manifestly originated in the purpose to open accessible interiors to the people, to afford them the opportunity of a distant outlook over the country, and thus to transfer to the tower the intervention of the church in life.

They replace in a more perfect way the usual terrace over the middle aisle on French churches that cannot be combined with t the plan of a single tower. But that the people took possession of the floor granted to them and then constantly enjoyed it, c can every one prove that seeks these places. Therefore we may not lack those parts of Germany above in the air, such as offered by the Freiberg and Strasburg minsters in their terraces, to which Goethe still drank golden Rhine wine; yet his relation to the Strasburg minster is not the last, which makes it of value to us.

Tabernacle forms instead of angle turrets.

The connection of the angle towers with the interior is wanting on the later German magnificent towers. The charm of those tabernacle forms, which only serve as crownings in Freiberg,

might well lead to elevating them as the chief object, i.e., to constructing the angle turrets more as angle piers that ever m more artistic combinations of figure shrines and finials, and thus finally forming mere show pieces, that rising from the base of the octagon as solid masses, only serve to load the angle p piers, but with all splendor missing what is found in Freiberg, namely the fulfilment of a purpose increasing with the whole.

On certain later works like the tower of S. Bartholemew in Frankfort, these tabernacle forms received a broader purpose, for they were characterized by little flying buttresses turned to the angle piers of the octagonal belfry and certainly as supports of the latter.

Continuation of the octagon downward.

As before noted,on the Freiburg tower the transition from the square to the octagon is already prepared in the story below t the belfry and corresponding to the church roof. A further advance consists in this, that the beginning of the transition is utilized as a motive for the treatment of the next to the last story for its full height, as on the towers of the cathedral of Cologne, on which the buttresses of the octagon of the tower extend down to the walls of the square to the cornice fixed by the height of the clearstory.

On certain smaller towers, like that of the Nicolai church in Frankfort and the chapel at Kidrich, the octagon of the tower extends itself down to the portal story. The transitions are l found above them on the first tower simply by washes, on the latter being effected by a tabernacle form adjoining the side of the octagon. That the carrying of the octagon deeper already occurs on Romanesque works was already mentioned on p. 571.

Placing the octagon diagonally.

The complete opening of the sides of the tower square by two windows as at Cologne and Ulm brings with it, that the angle f. pier of the octagon comes to stand on the arch od a window. The height of this transition is found in Cologne above the second story, on other towers above the succeeding story. This arrangement brings into expression the homogeneousness of the division into separate heights. If the octagon of the tower is displaced so that two diagonals of it coincide with those of the square (Fig. 1407), then results the necessity, on account of the increased thrust of the four transition arches at the angles and

loaded by the piers, to annange some piers strengthened by buttresses at the middle of the sides of the sjuare, as in the lower half of Fig. 1407, or where those transition vaults strike the walls as in the upper half, while the proper angle piers of the sjuare are relieved and are recessed in a rather idle position. The bisection of the side of the tower square by the middle pier can thereby be made at any division in height, butfirst over the projecting portal as in Fig. 761, the middle pier standing on the crown of an arch.

This bisection may then also result from the arrangement of the plan, especially if the towers belong to doubled side aisles as on the cathedral of Cologne, and is only avoided on the cathedral of Paris by that peculiar arrangement of the lower vault of the tower described more fully on p. 313.

Development and crowning of the octagon of the tower.

On the octagon of the tower all sides are opened by windows, or only those parallel to those of the square. The latter being when the other four sides are occupied by adjacent angle turrets or other transitions.

The arched openings themselves are single or divided by mullions, according to dimensions. Mullions are here indeed substantially ornamental, where glazing is not concerned, but make more difficult the placing of the louvre boards and therefore are n wanting on most older French towers.

The angles of the octagon of the tower appear as simple edges or are strengthened by projecting little angle columns bonded with the masonry or by forms of piers.

These little angle columns may either have their capitals in the cornice terminating the octagon of the tower as in Fig. 1403, or afford a support for the gargoyles at the base of the spire, or if the latter are wanting, may directly receive the ribs of the spire as in Fig. 1390, or finally if a passage is arranged at the base of the spire, pbear the pinnacles uhich rise to strengthen the balustrade. The angle piers as at Freiberg (Fig. 1404) may be formed according to two sides of the square or as ordinary chair buttresses, with their caps attached to the angles of the belfry, or also join those of the spire, or rising above the balustrade be crowned by simple or compound pinnacles, as in Freiberg (Fig. 1403) and Cologne. We however call attention to this, that in Freiberg the inner of the four

little pinnacles is omitted in order to avoid the reduction of the passage (d in Fig. 1404).

Stair towers.

Between those angle piers there extend the tracery gables on the said piers as on many others, that crown the arched openings and rising above the balustrades, which however differ in no essential respect from those occurring in other places. Only in Freiberg the tracery balustrades do not pass behind the tracery gables but terminate at them on both sides. This sixteen-fold crown formed by the tracery gables with the pinnacles offers a substitute for the eight little side turrets of the early French spire, yet we must say that it does not attain the grand effect of the latter, even if it already excels it in richness.

We have already mentioned on p 590 stair towers, which are enclosed by the angle turrets forming the transition to the octagon. These are opposed to the towers of Freiberg and Cologne, where is found a complete separation of both, when the stair towers are suited to their purpose and hence in entirely different form join the angle towers in their lower parts, but are f free from them in their height. Thereby the symmetry is certainly somewhat disturbed, since only one stair tower is needed, b but the picturesque effect is essentially increased.

On the later magnificent towers of Strasburg and Ulm on the contrary, entirely symmetrical designs are made possible, since each of the four angle towers becomes a stair tower. These stand entirely separate from the belfry, rise above the upper balustrade and are connected with its floor by bridges. On the Strasburg tower, whose construction up to the apex of the spire is determined in its character by the system of steps, evey this result is justified, this thoughtful execution, the almost modern design of three superfluous stairs, while in Ulm (according to the original drawing) the purpose of symmetrical execution at any cost still is certainly disturbing. The continuous cross bond that such stair towers receive by the steps, gives to them ar extraordinary stability and make possible the least thickness of the walls.

Yet we mention the perhaps unique plan of the stairs of the towers of Meissen, that are not arranged in a separate hall, but are found in the thickness of the wall, though in inclined straight flights along the sides of the square tower, these

being made visible by openings.

4. Smaller Turrets.

Little turrets above the western gable.

We have already given in Fig. 814 a an example of a little t turret, that is borne by buttresses projecting from the bable wall and is corbelled out from that. If the buttresses are wanting, the corbelling is naturally from the face of the gable wall and then must be stronger according to conditions. It is to be noted here, that on account of the corbelling, equilibrium at both sides must be approximately equal.

The ground form of such turrets can be the square or any preferred polygon, and indeed the small dimensions customary here make the hexagon particularly suitable.

The form of the corbelling is first determined by the section, and it may be in a radial direction by means of separate projecting and superposed courses, or be made by separate corbels covered by slabs or connected by arches. The first arrangement is less adapted to the square than to the polygonal form. The size of the loading further makes a steep direction of the corbelling preferable, which can be obtained by the profiles of the courses as also by separating the projecting courses by others ponded in the face of the wall.

The corbelling must always commence so deep, that from the attic floor is an access to the interior by means of a stair or a ladder, so that an opening can be made through the corbelling (Fig. 814 a) or above it.

The mode of treatment of such gable turrets is derived from that of the great towers with regard to the reduced dimensions and the changed construction.

Thus we have a belfry crowned by a spire and with open arches on all sides, under this being found a room with closed walls above the corbelling, which contains the bell cage. The angle piers of the belfry can be strengthened by buttresses.

On little chapels the gable turret sometimes shrinks to two side piers, which directly receive the axles of one or more bells. The piers are joined at top by an arch or are covered by a protecting roof.

Turrets above the triumphal arch.

Instead of gable turrets over the western facade, they sometimes appear above the gable rising above the apse. Finally

they sometimes rise from the roofs which then conceals the corbelling. In this case they are placed on the wall erected over the triumphal arch, like a rich turret at Clomar and one at Zwetl. Then the wall above the triumphal arch and beneath the turret can be opened into the attic; on the Maria church at Stargard it is opened to almost the width of the clearstory, so that the roof turret is borne by a great pointed arch, that is abutted entirely over the side aisles by bold abutting walls.

As the finest example is to be regarded the truuet mentioned on the church of S. Katrina at Colmar, that reproduces in small dimensions the design of Freiberg tower with all its magnificence, angle pinnacles, tracery gables over arched openings, tracery balustrades and perforated stone spire.

The smaller stair towers and side turrets also occurring elsewhere on churches exhibit forms like the principal towers, even if also mostly in simplified form. They frequently pass into t the form of pinnacles (See Finial).

5. Stone spires of towers.

Simple spires of cut stone.

Origin and use of stone spires.

Massive and also serving as a roof to cover the interior, they extend back in southern countries without wood into the earliest period of civilization. In Byzantine art are frequently found very commonly domical or conical and pyramidal stone roofs. The external and internal surfaces may have like forms, or may differ from each other as in Fig. 1408, which internally is a dome and externally shows a pyramid or a cone. Such domes or spires can be made entirely or partly of concrete, rubble, or consist of regular ashlars or of bricks. The regular stones appear externally, while the irregular masonry is either made even by proper mortar,or better has a protecting covering of tiles, stone slabs or even of metal (lead or copper). Those old buildings in the Caucasus are frequently animated by conical or pyramidal massive tower roofs of moderate inclination, that are covered by great slabs of limestone, on whose joints are cover stones as on Greek or Roman roofs.

Domical spires.

In northern countries somple thin stone roofs over closed rooms are unsuitable on account of the sweating of the inner surface in low external temperatures, but this is not in the way of their

use with the arrangement of isolating interspaces, if they a are well built otherwise; they are entirely suitable over open rooms beneath like the towers, where they still have over other roofs the advantage of power of monumental treatment, greater duration and of safety from fire. Therefore stone spires predominated in all mediaeval times and will also be again erected now, since they are worthy, not dearer but even cheaper than wooden spires. Their walls may be thin and their trust is quite unimportant with sufficient steepness. Since not only domes but also conical roofs and thereby polygonal pyramids are statically favorable forms of vaults (p. 56 and 604 later), their treatment permits great freedom and even complex corbellings, as on the towers of S. Paul at Worms,(Fig. 1409), but make no great difficulties. The towers of S. Leonard in Frankfort have domical roofs and a peculiar spire between a dome, cone and pyramid, below which is also found a transition from the square to the octagon worthy of consideration, as shown by the foundation church at Treysa in Hesse (Fig. 1410), that has come to us only in ruins.

For about 2/3 of its height, the spire is in the form of a steep pointed arch, and from thence with a scarcely noticeable b break it is made rectilinear. There are lost at the same height the angles of the octagon, which accordingly pass into the circle, as well as its construction is there transformed from that of the octagonal dome to that of a cone with horizontal rings. The heavy effect of the spire mentioned is nowise based on the line of a pointed arch, but results from the placing of the angles above the front face of the point of the gable. All from its low proportions. This curved outline is even found retained on certain Early Gothic great pinnacles of Freiberg minster, in a sense as an entasis, and likewise for its effect as a form as well as for structural reasons is preferable to the concave contours of spires occurring on certain late Gothic towers.

Pyramidal stone spires.

Generally in the Gothic period disappear the domical spires, and the octagonal pyramid ever predominates, but besides it are found occasionally the square or hexagonal pyramid and the cone; more on the form of the spire and this transition to it was already given in the preceding Chapter, but on the thickness of the wall etc., see the next Chapter.

For reasons of stability the spire rests on the inner edge of the wall (Figs. 1406, 1411), whereby the wall is also corbelled out inside somewhat. The projection of the wall is occupied by a passage or by an inclined covering (Figs. 1355, 1355 a). But it is equally possible to continue the external surface of the spire over the wall, thus cutting off the part c e d at the right in Fig. 1413. Since the centre of gravity of this part of the wall lies toward the outside, it adds little to the stability, and particularly for relatively thick walls may be omitted or even be objectionable. The remaining part a b of the wall at the left in Fig. 1413 must always be constructed as well bonded masonry, vertical on the inside or corbelled out if possible and of not too light material.

Direction of the bed joints.

Cut stone spires are built of horizontal rings or courses of uniform height, and thus can be arranged according to the usual dimensions of the stone. The bed joints may be horizontal or be perpendicular to the surface of the spire (Figs. 1412, 1412 a), the transmission of the pressure not being influenced thereby. Beds perpendicular to the inclination of the spire (Fig. 1412 a) have the advantage, that the stones retain their rectangular edges, and on the contrary have the defect that with bad mortar the rain can penetrate into the inclined beds, and further the joints at the angles are less simple. Horizontal beds avoid this defect and make it possible for a better transition to the stone courses of the tower wall, when the surface of the spire extends over them (Fig. 1413). The only objection to horizontal beds is the oblique shape of the stones, but which aside from the difficult erection of steep surfaces requires no consideration. For very flat spires both kinds of beds are unfavorable, one for t too great inclination and the other for the acute angles of the stones, and both for the danger of sliding inside or outside. Reducing the inclination generally increases the difficulties in every point of view, while the erection of slender spires is scarcely to be distinguished from that of an ordinary wall.

Generally horizontal beds will be preferred for cut stone, a and men have sought to avoid the acute angles of the stones in various ways. The simplest means is a stepped setting of the stones (Fig. 1414), the towers at Ver and Poitiers (Dehio and von Bezold, Plates 277, 278) present examples of this. For the

purpose of removing water more rapidly by washes on the projecting ring surfaces, appears to have required the animated motive of scales recessed upward, as on various towers at Periguex, M Massac, Poitiers (Dehio & von gezold, pls. 249, 277). Better is the purpose served by a slope of the surface of the ring (Fig. 1415), whether flat as a b or steeper as a c. So long as a little vertical part c d remains the acute angle is avoided, and further is obtained the advantage that the joint lies in a vertical instead of an inclined surface. As shown by Fig. 1415 a the advantages of this stepped inclination predominate over those of the simple one particularly for flat inclinations, and in fact it is employed in southern Fracce for roofs, that only have an inclination of between 30° and 45°. For steep spires it is only of value, when the small steps are not vertical in space, but are perpendicular to the wash (Fig. 1416). The beds can then be more effectively protected against the penetration of water by arrangements like Figs. 1417 and 1417a.. On steep German spires men have mostly been satisfied by a smooth external surface. On many French towers the projections (Fig. 1418) are utilized for carving scale work, whose angular or rounded points are turned downward (Fig. 1418 .). The scale work covers the entire s surface as on the north tower of S. Denis, or it alternates with plain bands as on S. Etienne and S. Pierre at Caen. The hips there receive projecting strengthening ribs with or without crockets. The upper solid cap of the spire that extends downward (mostly 2 to 4 m) can be characterized externally by a special treatment, for example takink the form of a colossal pinnacle. (Fig. 1419).

Stone crowning.

The most common stone crowning of the apex of the spire is a round, lenticular or richly profiled knob, that directly rests on the apex of the ribs or is raised by a stem; on Romanesque towers (like Worms) it often has a form and approaches the intersection of a sphere and cube. There frequently rises above t the knob a stone cross, also forms of animals, men or angels sometimes occur. The knob also takes the form of a cone or a bud, for which develops by the extension of leaves the cross flower with four, rarely with six or eight arms. Otherwise is applicable to the crownings what was said for finials.

Projection of crownings.

The projection of the crowning was not excessive in the better time, since it otherwise would easily injure the aspiring character of the spire and weaken the impression of the whole. As its construction depends on the dimensions of the ashlars, it is very natural for great towers to have relatively small crowns. First in the late time as for pinnacles the projection is placed more in a fixed relation to the spire, and thus became colossal crossflowers more than 3 m wide, only executed with great labor, as shown by the Liebfrauen church at Esslingen. Recently faults are frequently committed in crossings and in statues placed high, since men take too much account of the probable foreshortening, but a skilled eye is little deceived by foreshortening, unless with it is connected the concealment of a larger portion, so t that detached art works also have a good effect from a distant point, as being in almost geometrical elevation.

Security against overthrow.

Crownings are easily overturned by wind (for safety on account of vibrations, men reckon at least 200 to 250 kil wind wind pressure per square m of the greatest area of cross section). The upper stones must therefore have sufficient weight and before all a suitable base. For the crowning of Fig. 1420 would the bed be placed at least down at f f, but if necessary even at the middle of the knob e e. But both would only be sufficient with very great dimensions (here at least 60 to 90 cm width of bed), and for smaller dimensions the first bed f f must lie even much lower.

It would easily be overlooked that the stability of a body a against wind depends not alone on its form and weight, but also on its absolute dimensions. (The overturning moment increases only in cubic, but that of stability in biquadric proportion to the linear dimensions). While a stone cube with a side of 5 cm with a specific gravity of 2.4 may be overturned by a wind pressure of 120 kil per square m, a stone cube with a side of 50 cm would require 1200 kil per sq. m for this. Likewise with 200 kil wind pressure a prism of the same stone 100 × 100 cm must have 12 times that height (12 m), for a base 20 × 20 cm it could have scarcely 2 1/2 times that height (48 cm). In the same manner is it explained, that the wind may raise specifically heavy bodies in the form of grains or dust in the air.

If the crowning is too light, then ashlars are drilled verti-

vertically and an oron bar (far better a bar or tube of copper or brass, the latter as sheath for the iron bar) is passed through, and is held beneath the solid masonry apex for this purpose by a key (Fig. 1421 at b), the cotter, a plate or a weight. Recently these rods are generally combined with a lightning rod, which runs down outside or inside the spire. The solid masonry of the apex down to the internal width of 25 to 50 cm or more is usually advisable for practical and statical reasons, but much material is not necessary for this.

Iron crownings.

When the iron bar is once used, it is next to allow it to extend above the knob of stone or wrought metal, forming a cross, weathervane, star or other iron crowning. For example a cross may have a form according to Fig. 1421 by a projecting riveted cross bar with varied curved stiffening bars c placed in the four angles. It is made tight above the knob by a wrought projection a and also finally by also a lead flashing. Above the knob is twisted the square bar in the mode of Fig. 1421 a, end thereby the resistance to bending is made rather uniform in all directions. For larger crosses the bar requires stiffening by 2 or 4 braces at bottom (Fig. 1422), which rest on the knob or better extend down on it about as in Fig. 1423. (After Viollet-le-Duc, Vol. IV, p.428). Further on iron crownings that already occurred in a very early time, see on wooden towers.

Perforated spires of towers, passages, enrichment of angles, etc.

The spire may remain entirely smooth, or it may have strengthening mouldings on the angles and also at the middle of the sides (Chartres, Vendome), and besides bac enriched by scale workon the surfaces.

Dormers and slits.

But an effective animation is received by the surfaces of the spire by single or numerous perforations, that are desirable up near the apex on account of the escape of the air, but which a also find places elsewhere at differenh heights already on the towers of the transition style are added dormers or openings. an example of this kind is presented by the Liebfrauen chorch at Worms in Figs. 1424 and 1424 a. On French towers these openings are made very slender; also they occur without caps as long rectangular slits in the surfaces of the spires (S. Denis, Soissons, Rheims). They are very easily made, but at too great a height

are not strictly favorable, since with very thin walls they break too much in important ring stresses.

Polyfoils.

Richer and more animated appear openings of central form, that are cut out of an inserted large stone slab, or in the coursed masonry. They may lie at greater distances above each other as on S. Etienne at Caen, where they perforate the surface of the spire ebtween the scale bands in dimensions decreasing upward as sexfoil, cinqfoil, quatrefoil, and finally at top as three ever diminishing trefoils. On the towers of Seez they lie as cinqfoils close above each other and make room above for slender silts. Generally may the polyfoils and slits are connected alternately with rich surface ornaments.

Forms of tracery.

All forms of tracery, both windows divided by mullions (on the crossing tower at Lichfield in England even with rich tracery gables over them,) as well as combined polyfoils and roses could develop here, so that thereby they approach each other more closely and finally extend over the entire surface, their original and extremely airy and rich development of the spire, that chiefly occurs in the provinces of the former German empire and indeed finds its most perfect example on the tower of Freiberg minster

As other rich examples may be mentioned the minster of Strasburg, Liebfrauen church at Esslingen, whose spire was charmingly enriched by a passage near the apex, church of Thorn, the little tower on the cathedral of Meissen, the minster at Basle, cathedral at Burgos, the restored spire of the cathedral of S. Stephen at Vienna, and the particularly rich spires at Cologne, Regensburg and Ulm, that only came down to us in drawings, which have remained till our time for completion, and in part still so continue.

There is adready much dispute concerning the contradiction in the design of a perforated roof. If already it is not a lie, t that we have here to do with a developed structure rather than with a form developed from construction on account of its formal effect, certainly in a more perfect way, then the current applications are unfounded, and the principle that lies at the basis is indeed carried to extremity, but is nowise false. For first as the Freiberg tower shows, the perforated spire is not at all a roof, but it forms the upper hall above the belfry only enclosed

by eight slender piers connected by arches and thus open on all sides, whose stone floor is the actual roof, from which the rainwater is conducted by gargoyles.

If they in Freiberg that hall was never intended for a belfry, yet a use of it in that sense would easily be possible, when t the bell cage and the bells therein contained were protected by a roof above with louvre boards covered by lead fixed around it, as the case in the southern tower of the cathedral of Paris, (Viollet-le-Duc, Vol. II, p. 192), in the latter where the rainwater is freely admitted through the 8 great arched openings. Therefore since closing the arched openings with that covering of the bell cage became superfluous, the same case occurs in r regard to the roof, and thus a perforation of it must be allowable.

Accordingly the situation of the matter is about as follows. So far as nothing is found in the interior of the tower, which can be injured by rain, it is fully justified to allow it free entrance. But that in Freiberg nothing is injured must be proved by the duration of nearly half a thousand years. Just as well have the towers of Notre Dame endured with a perforated spire.

Therefore the design of such even represents the development of the highest magnificence, that also still has its rights. At least no one will easily doubt this, that has seen the crown of the Breisgau. But just as this splendor is the highest with regard to the date of erection as the last on the building, so t should it also be the last, and it is generally to be thought, that it should only be striven for when nothing else must be lacking. The crown alone ornaments the purple mantle, over which the ordinary covering would be puerile.

The effect of the magnificence peculiar to the perforated stone spire is entirely lost in its modern imitations in cast iron. It is a confusion of idea to compel the latter material to take a form entirely foreign to it. Every attempt is in reality nothing else, than if one were to require a cast iron lamp post arm to have the form and strength of a corbel. Indeed no objection could be raised to a cast iron spire in itself, whose forms were even developed from the nature of the material, but so far such attempts are lamentable failures, and especially as shown by the spire on the central tower of the cathedral in Rouen.

The construction of the perforated stone spire differs according to the dimensions.

Construction of the surfaces.

In smaller dimensions, which permit composing the side of the octagon of a single slab ir width, these slabs are so placed above each otner, that the butt joints alternate at the angles (f in Figs. 1425 and 1425 a). Thereby is determined the width of the plain surfaces accompanying the angles of the spire by the need of leaving to the slab the necessary thickness at the joint f.

The simplest case would then be as shown by Fig. 1425, to form quadrangular panels and arrange the tracery in them, so that the height of each panel should about equal its average breadth, or to give all panels approximately so that the lowest panel is n nearly square.

Greater freedom in the treatment of the tracery results from abandoning the quadrangular form of slab and the allowance of bed joints which directly cut the bars of the tracery at right angles (Fig. 1426). According to the same system in larger dimensions the separate sides of the octagon may be composed of several pieces in width, alwans with the condition that the joints cut the bars of the tracery at right angles.

But there as in a horizontal arch occurs a pressure of the s separate pieces toward the angle, thereby producing in the latter the thrust directed outward, they weaken.

Aresistance to the latter results from the weight and the stiffness of the projecting ribs, either at one or both sides, whose construction is nearly analogous to that of the ribs; i.e., the separate pieces of them rest on each other and receive the perforated slabs of the walls of the spire, as the vault ribs at the masonry of the compartments. Therefore in plan they receive in the simplest case about the shape given in Fig. 1427.

Just as the ribs of the spire prevent by their dimensions the deflection of the walls, so do the walls prevent any bending of the ribs toward each other. To increase this resistance and generally for a stronger connection in larger dimensions, the separate tracery divisions must pe divided at certain heights by h horizontal long slabs or stone beams, which lie as ties between the ribs and form firm bands around it.

Fig. 1428 represents the lower part of an octagonal side of the Freiberg spire, where the ribs proper do not project outside, while the piece v on which rest the crockets has little structural

importance and those ribs are set with only one tongue and further are connected by single iron pins.

For the height of each division the ribs consist of two or more stones set on end and on each other, between which are inserted the separate tracery slabs, so that the plan at the height concerned shows the arrangement of the joint in Fig. 1404. A further connection with the tracery slab is then made by a header a, at the height of which falls the joint marked f. On the headers a are then laid the long pieces b, whose butt joints sometimes are at the middle and sometimes in doubled number at both sides about as at x, are again connected by the piece d lying thereon, so that a bond is formed at each division of the tracery in height, whose permanence can be ensured by a connection with tongue and groove in the bed joint, as shown by the cross section in Fig. 1428 a, or completely by dowels.

In the succeeding divisions of the Freiberg spire the headers a are omitted, and the end joints f extend through to the horizontal band, which then again are connected with the ribs by the pieces b and d as headers.

The peculiar system of this construction is not clearly expressed in the Freiberg spire, since each horizontal band is no more indicated by projections than the ribs.

From the original drawings of the towers at Cologne, there appears to result a consistent construction of the ribs and bands, in so far that both parts are indicated by bold members, and t thus form a framework, in which are inserted the slabs perforated in tracery. By this may then the permanence of the band either be produced, the two courses lying over each other being alternately end joints, or with this alternation of joints is produced by its connection with the tracery slabs lying above and beneath it.

Development of the ribs.

The ribs, which have such an essential place in the construction of the perforated stone spire, are also found on the unperforated spires in order to strengthen the angle connections and chiefly the angles, and they are then either and indeed best formed on the ashlars of the separate courses, thus requiring a greater thickness of them, or in rarer cases, like the piece r on the Freiberg spire (Fig. 1428), they are attached to the hip and fastened there by separate headers.

From the headers could extend the crockets, which would only require a greater length, if they were not originally found at other places, like the pinnacles and apexes of gables, so that the transfer of them to the spire for their decorative effect is to be assumed as determined. On the Freiberg spire then are made in the same pieces with these angles as already mentioned above, and later were fastende to the spire by iron clamps. Yet this construction is only to be regarded as a help in need, the cutting them in the ashlars of the courses or a deeper insertion in the angle of the spire is likewise to be preferred in every case. To the size and spacing of the crockets applies what was said concerning pinnalces, i.e., neither can be assumed a relation of the number nor size to the dimensions of the spire. Before all is required a clear and easily recognizable form, so that already on this ground the older and volute forms deserve preference. On one of the original sketches of the tower of the Strasburg minster, they are replaced by an arch with cusp, which also occurs on the tracery gables.

Passages and intermediate stories.

The dormers opened in the spire (Fig. 1424) utilize the wall of the spire to support the vertical front and side walls; such a moderate load reduces the stability very little. Never injurious and often useful to stiffen the bond appear those passages placed on projecting cornices with perforated balustrades (Fig. 1430), as they are simply found forming four gables above the base of the spire on the Marburg towers. On certain works of the later time are then frequently repeated, most extensively on the original drawing of a tower of the cathedral of Regensburg, where then above the angles of the spire they have piers crowned by pinnacles, that below the bases of the pinnacles are connected with the ribs of the spire by flying buttresses, that again join below the corbelling of the nearest balustrade above them. In such a form they dominate the entire structure and nearly neutralize the effect of the ascending line of the spire.

From the same structural principle results the design of an intermediate story opened by windows at a proper height of the spire, whereby it is separated into two divisions, about as in Fig. 1429. The thickness of the vertical walls of the intermediate portion can be greater than that of the lower wall of the spire, and must suffice to resist the thrust of the upper part.

Below the vertical wall results no difficulty, since here the pressure in the bond equilibrates all (p. 614). The thickness of the walls of the two portions may differ.

Stairs and pinnacles on the angles.

The grandest and most spirited application made of the supporting power of the spire is shown by the north tower of Strasburg minster. The construction of this is so well known an is represented so masterly by Viollet-le-Duc (Dictionary, Vol. V, p. 439), that I shall here limit myself to a bried description of the system.

For at the height of the base (Fig. 1431) a stair tower projects from four of the six angles of the spire, whose newel stands at the angle a, and which only contains the steps from c to d. From the first is then developed a second stair tower, whose piers e and f stand on those of the lower part of the tower, while g and h rest on the walls of the tower, the front corner pier being placed on the newel a. This second stair tower contains the steps from d to i, and supports in the same manner a succeeding one, so that the course of the steps follows the dotted spiral in Fig. 1431. There are now developed on each angle six of such stair towers over each other, by which one reaches the height of a landing from which a stair winding around the centre of the spire reaches a middle turret crowning the spire. Between those eight stair towers the walls of the spire are richly decorated by tracery.

Such loading of the rib of the spire is often very favorable statically (p. 609), and in another form is expressed by the change of the crockets into pinnacles, whose supports are cut on the ashlars of the spire, while the body and finial are made of separate pieces. An example is shown by a stair tower on the south side of Strasburg minster. Yet this produces a peculiar spiny appearance.

Brick spires.

The erection of sipres in brickwork follows substantially the same principles and only requires simpler design and details, and there the bed joints may like cut stone spires be normal to the inclination of be horizontal. Yet horizontad beds either demand bricks of special shape or a stepped surface. Still on account of the height and the steep inclination, the resulting small width of the steps is scarcely perceptible from below.

Ornamentation of the surface results most simply and suitably by a pattern made of bricks of different colors.

As in stone spires the termination will be of solid masonry, and the crowning will either be of cut stone set there, an ornament of terra cotta, or finally only by a lead cap covering t the base of the iron rod and the joints, which is then capable of any richer form.

In a manner entirely similar to that of stone spires, there may also be formed here openings of different shapes, first being simple slits, then those openings formed like dormers about as in Fig. 1432, yet the latter only with horizontal joints. The position of joints normal to the inclination makes possible certain circular or polygonal shapes, thus more openings like tracery (Fig. 1432 below), that are naturally often enlarged a and occupy large surfaces. A complete perforation of the brick spire like one of stone with special shaped tracery parts however does not exceed the limits of possibility, but still is not advisable.

Generally the durability of good brick materials is also subject to certain limitations in a place exposed to weather in s such a high degree. One must avoid too ornamental details, also with the use of a thickness of only half a brick walls for the smaller spires or for the upper part of larger towers, men must be careful unless the best material (best glazed hard clinkers) and reliable waterproof mortar (tolerably rich cement) are used. Good glazing can substantially increase the durabilitn of bricks, for which proof is given by the so-called blue tower at Lübeck dating from about the 15 th century, whose walls are constructed with alternating red and black glazed bricks, the former being corroded for several inches in depth, while the original surfaces remain on the latter. Glazing badly crumbled and with many hair cracks may be more injurious than useful. As a defective substitute for good glazing or other bricks resisting weather may serve a coating of the best possible mortar, which also occurs on stone spires of rubble masonry, and is found on the tower at Treysa represented in Fig. 1410 and the Eschenheimer tower at Frankfort. The mortar must be replaced after injury by weather, since otherwise the softer bricks beneath it will be attacked at injured places, and in this consists the defect of the coating, which otherwise as a coating is inferior in style to

the appearance of the proper material, but is not to be rejected so long as it does not imitate a different material.

For the construction of the angles are required bricks of special shapes already on account of the obtuse angle, which can then be furnished with a projecting member. But this contributes but little to the very desirable strengthening of the hips with the thin walls of the spire, and therefore is better a bonded projection in bonded masonry according to Fig. 1433. A strong bond at the hips and the internal strengthening or at least an internal filling of the angle is very advantageous. For richer ornamentation the ribs or angles without ribs can be combined with crockets of terra cotta or better of stone.(Fig. 1434).

6. Stresses, thickness of walls required and thrusts of masonry roofs.

Conical spires.

If it be desired to support against each other two thin walls in mortar unable to resist tension as in Fig. 1435, then the m masonry will fall inward after carrying the uppor portion up h high. If it could only be made durable so that the upper angle can be made solid, so that the line of support can find its place within it (Fig. 1436), or such a great load be laid on it, that a correspondingly steep line of support can be formed therein (Fig. 1437).

It is otherwise for a roof of conical form, here also the parts of the struts that would fall in hinder each other, when they support themselves against each other in the form of a ring (Fig. 1438). The masses pressing inward produce a ring compression, which is the greater, the flatter the cone.

Ring compression and longitudinal compression.

Therefore in the cone are to be distinguished two kinds of compression in the covering surface:-- 1, a ring compression t that is strongest below and gradually diminishes upward till it becomes 0 at the apex; 2, an oblique compression directed downward, that by the effect of the weight of the stones is transmitted from stone to stone, and thereby also gradually increases from above downward; it may be termed longitudinal compression. For a cone under the influence of its own weight it may be assumed with sufficient accuracy, that the longiludinal compression in the sides passes down at the middle of the thickness of the wall, for if it would take a different direction, then the

ring compression acts to equilibrate it, an advantage that the conical vault has in common with all domes compressed in the direction of a ring (p. 55).

Load on the abutment and thrust on it.

The compression of the conical spire on the walls becomes very simple under this assumption. It is just the longitudianl compression acting in the inclination of the covering around the entire cone. To find it, a narrow triangle is taken from the apex to the base of the covering (Fig. 1439). At its centre of gravity O is applied its computed weight G, and from O is laid off the weight G vertically, and from O is drawn the line S with t the inclination of the cone, then from A is drawn a horizontal H, and the compression S sought is found in direction and magnitude. Equally simply is it found by the equation, $S = \frac{G}{\sin a}$. (Here a is the angle of inclination of the cone, so that sin a = height divided by length of slope).

Instead of this compression S acting obliquely on the abutment, it is more convenient to calculate with its components (see bottom of the Fig.). The vertical component loads the abutment and equals the weight G of the corresponding portion of the cone; the horizontal component H forms the thrust against the abutment, and is found by the parellelogram of forces (at bottom of drawing), or yet more simply from the already mentioned triangle of forces O A B, whose base represents its magnitude. Instead of drawing it, this may be calculated from the equation:--

$$H = G \cot a, \text{ (or } H = \frac{G\,r}{h}).$$

The thrust H acts radially at the entire circumference' if in the preceding equation for G is substituted the weight of the entire cone, then is obtained the sum of all thrusts acting at the circumference. If it be desired to obtain the thrust for a smaller portion, for example $\frac{1}{12}$ of the circumference, then this total thrust is divided by 12, or there is substituted in the preceding formula only 1/12 of the weight of the cone. Also for such small portions of the circumference (Fig. 1440) the thrusts still diverge somewhat, so that their resultant will be somewhat smaller than their sum (in proportion to the length of the chord to the length of the arc); but the difference is but small, amounting for 1/12 the circumference to about 1 1/2 per cent, for 1/6 circumference to about 5 per cent, for 1/4 to about 10 per cent, for 1/3 to about 17 1/2, and for 1/2 to 36 1/2 per cent.

The computed thrusts can thus be reduced in this proportion, if the correspondingly large portions of the wall can be regarded as sufficiently connected together. For a square tower as a rule can be taken 1/4 the perimeter in consideration (indeed with the angle) for an octagonal tower with round spire correspondingly 1/8, and for circular walls a piece of the wall between the larger window openings, or also a linear m of the perimeter, whereby the calculation is indeed abundantly safe. Otherwise the calculation of the abutment is exactly the same as for vaults (p.140).

Thrusts for different heights of the spire.

For equally heavy spires of different heights the thrust is about in inverse ration to the heights, as for example if the height be to the bottom width as 4 to 1, the thrust is 1/8 of the weight; for a height of 3 to 1, the thrust is 1/6 of the weight; for 2 to 1, it is 1/4, but for 1 to 1, it is 1/2 the weight, for half the height (inclination of 45°) the thrust is equal to the weight.

Otherwise the proportion of spires of equal weight be not compared, but those of equal thickness of walls, whereby the low spires weigh less than high ones, so that almost exactly the same thrust occurs for spires of sixfold, fourfold or double heights, first if they are yet lower, the thrust notably increases (see last column of Table on p. 607).

From this may one conclude, that on account of economy of material it would be preferable to make spires flatter, but this is not so, for just the greater weight of the high spire that rests on the inner edge, and thus on a very favorable place on the resisting wall, lends to it a greater stability. A comparison of the forces acting of the abutment in Figs. 1441 and 1441 a best represents this. Moreover tall spires are more easily erected, entirely aside from their more preferable effect architecturaly.

What is said here on conical roof almost exactly applies also to the thrust of pyramidal spires (see below).

Neutralizing the thrust by tension rings.

The thrust of the cone may be received by a tension ring instead of the stability of the wall, where a tension $Z = \frac{q\, r^2}{2 \sin a}$, or $Z = \frac{G \cot a}{2\pi}$, prevails. G is the total weight of the wall, q is the weight of 1 sq. m of the surface of the covering, a is the angle of inclination, and r is the radius of the base.

Let there be obtained the magnitude of the thrust and of the

tension in a ring at the base, for a conical spire of brick masonry 25 cm thick and weighing 1800 kil per cu. m, with 6.0 m inside and therefore 6.5 m outside diameter, with 3 1/2 fold h height, hence 21 m inside and 22.75 m outside.

The weight is by subtraction of the hollow from the solid volume of the cone, and this amounts to; $G = \frac{1}{4} \times 6.5^2 \pi \times \frac{1}{3} \times 22.75 - \frac{1}{4} \times 6^2 \times \pi \times \frac{1}{3} \times 21) 1800 = 97,000$ kil. The total thrust = $H = G \cot a = 97,000 \times \frac{1}{7} = 14,000$ kil in round numbers. Since the circumference amounts to about 20 m, there is 700 kil thrust per linear m. The tension in the ring = $Z = \frac{G \cot a}{2 \pi} = \frac{14,000}{2 \times 3.14} =$ 2,200 kil in round numbers. But this is a very small ring tinsion, that may already be received by an iron ring of 3 sq. cm in cross section. Instead of it this small tension might pe neutralized by a circle of stone slabs or ashlars interlocked or clamped together at the lower part of the spire or upper part of the wall, and also the simple indenting and resistance of the masonry to tension will mostly suffice for it. If the masonry has a tensile resistance of only 1/2 kil per sq. cm, 1/2 sq. m. cross section of the wall ring, thus an enclosing wall of a few courses 2 or 3 bricks thick suffices to neutralize the entire thrust of the spire. But since a greater height of the wall may have an effect, the tensile stress almost disappears. Thus when one counts on a certain and even so small tensile resistance of the masonry, that certainly on account of any vertical cracks in unequal settlement has a certain consideration, then the effect of thrust of steep tower spires on walls need not be considered at all.

Calculation of longitudinal and ring stresses.

To compute the longitudinal stresses in the cone at any point, one conceives a horizontal plane cutting across the cone, and employs the formula already given:- $S = \frac{G}{\sin a}$, where G = weight of the entire upper part of the cone cut off, or may represent a triangle of this, while S correspondingly denotes the longitudinal compression at the entire circumference or at the base of the triangle considered.

The ring stress is obtained by the formula:- $U = \frac{g \cot a}{2 \pi}$.

If one conceives that a ring is cut from the cone by two parallel horizontal planes, and its weight is computed, which is introduced as g in this formula, this gives the ring stress occurring in the ring cut out. If the sum of all ring stresses a

acting from top to bottom is to be obtained, this is only the entire weight G of the cone, that is to be substituted for g; t then is obtained exactly the same value that occurs below as tensile stress in a tension ring to neutralize the thrust.

For cones of uniform weight of the covering (g for 1 sq. m area), the longitudinal compression and ring tension as well as the thrust are also found by the formulas:-

$$s = \frac{q}{2h}(r^2 + h^2); \quad u = \frac{q\,r^2}{h}; \quad b = \frac{q\,r}{2 \sin a}.$$

Here s = longitudinal compression per m of circumference, u = ring stress per m length of covering in vertical section, and b = thrust per m of circumference. Then r and h are radius and height of the cone from the point of the covering considered. It is to be noted, that cones with equal thickness of wall is not synonomous with cones of equal weight of wall, but that the difference is small, if all dimensions are referred to a m mathematical conical surface lying in the middle thickness of the wall. The preceding formula makes possible a comparison of the longitudinal and ring stresses, which are equally great at each point for a cone of 45° inclination, and otherwise increase in proportion to the height. For flatter cones the ring stress exceeds the longitudinal compression, but coversely for steeper cones the ring stress is much the smaller. The succeding Table gives the relation of longitudinal and ring stresses for different inclinations.

Stresses in conical roofs of masonry.

(See Table on p. 607).

Example. A great tower spire is 12 m wide (r = 6 m) and 48 m high, of cut stone weighing 2400 kil per cu. m, for a wall 40 cm thick has a weight of q = 2400 × 0.40 = 960 kil per sq. m of surface, and thus according to the Table exerts at base a longitudinal compression per m of circumference of $4\frac{1}{16} \times 960 \times 6$ = 23,400 kil. Hence 1 sq.cm would be stressed $\frac{23400}{4000}$ = about 6 kil. Conversely, the ring stress at the base would be only = $\frac{1}{8} \times 960 \times 6 = 720$ kil per lin. m of inclined surface, thus per sq. cm it only is $\frac{720}{4000} = 0.18$ kil stress. The same stresses in both directions would also result for greater or lesser thickness of the wall.

Required thickness of wall of spire.

Since the stress in the material is independent of the thick-

thickness of the wall, one would then be able to build a cone loaded only by its own weight as thin as desired. By unforeseen oblique loads, but especially by the wind pressure, that may m materially and substantialln displace the stresses (chiefly in the direction of a ring, which prescribes certain limits. Under the effect of wind, the ring stresses no longer retain the accurately course, but at the windward side and opposite this on the external surface and on intermediate points are moved nearer the internal surface, whereby greater angle pressure as well as tensile stresses may be produced, indeed most easily on spires with very small ring compression (slender spires and domical curved spires are opposed to the wind pressure rather at a disadvantage). When the masonry is only rather more secure by strength of mortar or by indenting, any danger from wind almost entirely disappears. In general may one assume, that a thickness of the wall of from 1/24 to 1/30 of the width for light material and of 1/30 to 1/36 of the width for heavy and strong material suffices, but that one can go yet farther for particularly good construction, especially if at certain distances in height are built internally projecting and strengthening rings.

The thickness of the wall can be made uniform up to the apex or be diminished upward. Brick towers can be made 1/2 brick thick for a lower diameter of 3 or 4 m up to 1 brick for 7 diameter. If the spire must be less than 1 brick thick, then it is most advisable to carry this thickness to the apex, because the lesser thickness in the upper part reduces the weight little, but therefore requires more careful construction. For somewhat greater widths the change to 1 1/2 bricks may be by internal projections of rings and ribs. The conical spires of brick on mediaeval towers mostly have a thickness of 1 brick.

Overthrow by wind.

The danger of the overthrow of masonry spires by wind is not great, it occurs with 200 kil wind pressure per sq. m of the full cross section for brick towers 1/2 brick thick, or correspondingly heavy towers of cut stone with 5 to 6 fold height, f for spires 1 brick thick the danger of overthrow no longer comes into consideration. On the location of the kern of the compression and of angular compression by wind, see farther below (p.627).

Circular compression.

The stability of the spire is best ensured, if the thickness

of its walls be made so great, that a circle can be described in the ground plan, whereby this ring-shaped transfer of the compression is,made possible as in the cone. Therefore for the octagon a thickness of the walls of at least 1/24 of the clear width is necessary, but it is better to take 1/20, so that the circle may remain at a distance from the angles. Most easily t the circle cuts inside at the angles a, and therefore for other reasons an internal strengthening b, c or d is very advantageous, since it makes possible a ring-shaped transmission of the compression with walls of 1/24 or even 1/30 of the clear width.

Polygonal compression.

If the walls are so thin that a circle can no longer be drawn within them, durability is not thereby excluded, for segmental arched lines of support can be drawn within the sides (Fig. 1443), which intersect at the angles in a point F, there producing a resultant E directed outward. While thus the masonry of the sides presses inward by its gravity, the angles of the spire seek to press outward. The latter can be equilibrated by sufficient weight Q of the hips or ribs, that presses inward with a force = Q cot a (see further below under wind pressure). If the weight of the hip including the strips of masonry connected therewith at both sides does not suffice for this counter pressure.

Stresses at top and bottom.

There finally remains also the possibility, that the hatched portion C D in Fig. 1444 is thereby preserved from falling, that it acts like a straight ascending arch, which at the bottom C and the upper point D naturally produce great end pressures (reaction compressions). It is therefore a condition, that the upper part of the spire at a greater height downward can be considered as a firmly connected loading body. Farther below the shorter slips E F (Fig. 1444) may again act in the same manner.

Since the different possibilities of action reciprocally increase each other, the octagonal spire appears as a statically favorable form, so that it can be constructed in approximately is small thickness as the cone. Even thickness of the walls under 1/24 or that of the strengthening angles under 1/30, aside from wind pressure may still be permanent, particularly of a very small tensile resistance of the masonry must come in question.

Most easily could an injury occur by a settlement of the masonry under the middle of each side and as a result of this a b

breaking down of the hatched portion in Fig. 1445, which thereby loses its connection with the other parts of the spire and with the lacking ring compression might fall in without endangering the rest of the spire. But even this would be possible with greater pressures and would be hindered by good indentation.

Wall crushed inward by the wind.

The wind pressure tends to crush the wall in, and it would therefore be opposed as above by a line of support (Fig. 1443), and this again produces at the angles a force E directed outward, which must be neutralized by the load on the hip. The weight of the hip itself, even with the strengthening outside and inside is alone mostly too small for this, so that it is desirable to transfer to them the load of the wall surfaces by arches with or without openings in them (Fig. 1446), but which must not be too flat on account of the effect of the thrust. The same purpose can be fulfilled by variously shaped openings (Fig. 1447), which at the same time reduce the surface affected by the wind pressure. The openings are also statically not without importance.

Just on slender spires, which have but a small ring compression, is most easily possible in the lower parts a crushing of the walls inward by the wind. Then in order to resist the forces E pressing outward (Fig. 1443), there often does not suffice the weight of the hip even by the addition of the weight of the walls, so that greater stiffness against bulging must be given by projection of the ribs externally and internally, so thatin a diagonal section may be formed a line of support as in Fig. 1448. This line of support can then increase the thrust slightly at the base of the spire (which does not injure the abutment, since this occurs only on the windward side), further requires the line of support, so that the upper part of the spire acts as a connected and loading mass, and hence a reduction of the thickness of the walls above is not favorable.

For walls much too thin this also is not sufficient, for the stress from the wind is nearly in inverse quadratic proportion to the thickness of the walls, and there are only two expedients; the flexure stress in the wall or the projection of strengthening rings in the intermediate ribs.

Resistance of the walls to bending.

The bending stress assumes the existence of a certain tensile resistance of the masonry. It is well possible to count on that

that in this case for carefully executed masonry without cracks or strong pressures, in a moderate degree, for the tension occurs in a horizontal direction, where besides the resistance of the mortar the friction of the indented and load stones opposes, while For tension in a vertical sense the mortar in the bed joints comes in question. But if one desires to arrange so that tension shall not need to be relied on at all or only in the heaviest storm, then for thin walls as an extremely effective means of stiffening is the use to be recommended of compression rings most simply projecting inside (Fig. 1449).

Stiffening rings.

These are spaced eight to twelve times the thickness of the walls, 20 to 50 cm thick in the direction of the height and with a horizontal width of 1/15 to 1/18 the width of the tower at t the place considered, if the ring is found inside; but 1/12 to 1/15 if it remains internally octagonal. (In this thickness is included the thickness of the wall). The thin wall acts under the effect of the wind and also of its own weight between the rings above and below like an ascending straight arch. For very large spires it may be further required to arrange one or two middle strengthening ribs extending downward on each side surface in addition to the angle ribs (Fig. 1449), to which is given somewhat smaller dimensions than those of the rings.

Thickness of the walls.

If the walls of the spire have been divided by such ribs and rings into panels, whose dimensions at most are 8 to 10 times the thickness of the walls, then can the latter be restricted to 1/24 and even to 1/36 of the width of the tower, while otherwise they should not be made lass than 1/16 to 1/20 of the width, especially when the hips also remain without ribs.

Of the oldest examples may be mentioned; the unperforated spire of the Liebfrauen church at Worms (Figs. 1411, 1411 a), whose walls are 1/19 of the width (abutment walls beneath are of rubble 1/4 to 1/5 the width and are moderately opened), the perforated spire of Freiberg tower (Figs. 1406, 1428), whose walls are 43 cm thick for about 11 m width and must be termed quite bold, since the hips project but little, and the rings or bands between the traceries not at all. In a strong wind the Freiberg spire is exposed to strong stresses, which would not be the case with strong rings, even with thinner walls. Also the high and

narrow piers of the belfry are scarcely 1/6 of the clear width and are to be termed very bold abutments.

Calculation of the thrust.

The thrust of polygonal spires is again calculated by the formula; $H = G \cot a$.

If then G = the entire weight of the spire, then H = the corresponding thrust at the entire circumference of the base; conversely if G = weight of one side of of a angle (thus = 1/8 the weight of the spire for the octagon), then results only the thrust belonging to this part. As the angle a is to be taken according to circumstances the inclination of the side surface or t that of the hip, which is somewhat flatter, or a value lying between the two is to be used. If the weight of the spire is mostly carried down by the hip, then must the angle a correspond about to the inclination of the hip; since this is the most unfavorable case for the amgnitude of the thrust, thus it is well to calculate with it for safety. If one also makes the somewhat too unfavorable assumption that the thrusts occurring for an eighth of the spire act with their full amount in the direction of the diagonal, then has been taken an assumption as a basis, by which the abutment piers will not be too weak.

Naturally the aputment pier or tower wall must be sufficiently strong, that it may resist also the wind pressure striking it and the sfire. If the angle piers of the tower are connected together at certain heights by masonry, it is unnecessary to investigate the stability of the separate piers, but that of the entire mass, (thus of the entire hollow prism of the tower), whose stability against wind is considerable larger (p 636). Otherwise the calculation of the abutment is completed just as for that of the vaults.

Calculation of the longitudinal compression.

The longitudinal compression in the covering surface and ribs acting downward is calculated by the formula:- $S = \frac{G}{\sin a}$. In regard to the values of G and a the same is true, that was just stated concerning the thrust. Whether the horizontal compression constantly increasing downward acts more in the sides or is transferred to the hips depends on the construction of the spire as shown (p 609 above).

Calculation of the ring compression.

The ring compression, if the weight of the spire (or the long-

longitudinal compression) is pretty uniformly distributed over the perimeter, is transmitted in about a circular form, but if the weight on the contrary is exclusively carried down in the hips, as for many perforated spires, then is formed a compression polygon, whose angles lie at the hips. For intermediate cases results a polygon with sides somewhat curved outward.

In the first case for the compression circle the compression is:-

$$1. \quad U = \frac{G \cot a}{2\pi} = \frac{g \cot a}{6.283} .$$

For the compression polygon it is:-

$$2. \quad U = \frac{g}{n} \cdot \frac{\cot a}{2 \sin \varphi} .$$

Here g = weight of the ring cut out from the spire, a is again the angle of inclination, which in the first case is betwwen t that of the side and that of the hip, and in the second case is to be taken that of the hip. n = number of sides of the polygon, thus = 8 for the octagon. φ = angle at the centre for one side of the polygon, thus = 22 1/2 for the octagon, and consequently sin φ = 0.3827. Then formula 2 will become for an octagonal spire;

$$2\,a. \quad U = \frac{g}{8} \times \frac{\cot a}{2 \times 0.3827} = \frac{g \cot a}{6.123} .$$

If there be inserted in formula 1 for a the angle of inclination a_o of the side and in formula 2 a the inclination a_1 of t the hip, then will be obtained the upper and lower limiting values for the ring compression in the octagonal spire (see Table).

For a spire without openings the compression U acts in the entire height of the ring considered, which may be assumed 1 m high in calculating example 1.

Stresses in perforated spires.

For perforated spires the height of the rings to be considered is arrarged according to the kind of openings, as in the hatched surface in Fig. 1450. Since where the width of the ring is narrowed as at a b, the ring compression must be transmitted through this small cross section. It is similar for a spire entirely divided into hib ribs and bands is in Fig. 1451. For this is found by formula 2 the ring compression, that the bands receive lengthwise, when the weight g is inserted for a horizontal piece of the spire from centre to centre of the rows of panels.

Such a spire is a completely developed framework in space with members all compressed. The ring pressure or correct polygonal compression is received by the series of bands, and the longitudinal compression by the hip ribs, to which the bands transfer their own weight and that of the panels resting on them.

To calculate the magnitude of the longitudinal compression accordingly in the formula:- $S = \frac{G}{\sin a}$, are to be inserted for G the weight of an eighth of the spire and for a the angle of inclination of the hip. Under such assumptions is found there, H = G cot a = horizontal thrust acting at each angle on the wall of the tower.

The band best consists of one long stone with sufficient resistance to bending, so as not to break. But if it must consist of several pieces, then can it easily exert a thrust on the angle piers like a straight arch, whilh tends to bend them outward. it is then advisable to arrange the tracery in the panels so t that it supports the middle of the band. For very wide panels can be added even intermediate ribs carried down for this purpose. The tracery in the panels serves in just the same manner for resisting the wind as the X-braces of the wooden spire, to which these perforated stone spires in general are very nearly allied. (See below).

Comparison of stresses and thrusts of spires of different heights.

To give a clear view of the stresses and thrusts of polygonal spires of different heights, there is established the following Table; the first flat roofs are scarcely erected, but are added for comparison. Generally the stresses vary little from those of conical spires of equal height.

Stresses in octagonal stone pyramids.

(See Table on p. 612).

G is the total weight of the spire above the point considered.

Example. A brick spire 25 cm thick is octagonal with 6 m internal and 6.5 m external width, with a fourfold height of 26 m outside and 24 m inside. A cu. m of brickwork weighs 1800 kil.; the magnitudes of the stresses and thrusts are to be calculate. Volume of a solid octagonal pyramid = $0.829\ B^2\ \frac{h}{3}$; the existing hollow ~~afxxkx~~ pyramid has a volume accordingly with a difference from the solid of ; $0.829\ (6.5^2 \times \frac{26}{8} - 6^2 \times \frac{24}{3}) = 65$ cu. m in round numbers, so that this weighs $65 \times 1800 = 117{,}000$ kil = G, and 1/8 of this weighs 14,625 kil. According to the preceding Table the longitudinal compression at most = $1.009\ \frac{G}{8}$, here = 14,757 kil, or at least = $1.008\ \frac{G}{8} = 14{,}720$ kil. This is distributed over 1/8 of the base, which is an area of $\frac{1}{8} \times 0.829(6.5^2 - 6^2) = 0.647$ sq m or 6470 sq. cm and for uniform distribution = $\frac{14730}{6470} =$

about 2.3 kil per sq. cm, but would be considerably more with perforations or unequal distribution. (Strictly taken it is not the area of the plan, but that of a section perpendicular to t the rib, that must be taken in the calculation, but this makes a scarcely noticeable difference formsteep spires).

To find the greatest ring compression, there is considered a ring 1 m high, whose volume is the difference between the solid and hollow pyramids being shortened about 1 m is calculated at about 5 cu. m, which thus weighs 9000 kil. According to the Table the ring compression lies between 0.02 × 9000 = 180 kil and 0.22 × 9000 = 198 kil. The cross section of the ring is about 1/4 sq. m or 2500 sq. cm, and thus exists per sq. cm the extremely small compression of 0.072 to 0.079 kil, thus not quite 1/10 kil per sq. cm. The ring compression for the entire height of the pyramid at most amounts to 0.22 × 11.7,000 = 2574 kil, and just as great would be the tension in a ring of the base to resist the thrust.

The thrust is computed for each angle to be at most = 0.135 × 14,625 = 1974 kil, but it would probably remain under 1900 kil, and the abutments must suffice to receive it (see above conical spires and vaults.

Hexagonal and square spires.

The data and formulas for octagonal spires apply likewise to spires of other polygons.

The hexagon and pentagon do not often occur (at Pressburg two monastery churches present an example of eamh), but on the contrary square spires are not rare in the early time. The less t the number of sides, so much the more are the difficulties increased, since the important ring stresses are incomplete. Particularly unfavorable appears the wind pressure against large surfaces. The expedients mentioned, such as stiffening rings, strengthening the hips and the middle ribs, the latter eventually extending to the vertex and even in arched form could thereby serve to reduce the otherwise very great thicknesses of the walls to be employed.

Spires with curved sides, domes.

Possibility of different cross sections.

Polygonal or round stone roofs, that exhibit concave contours in elevation instead of straight lines (Fig. 1452, left), have greater ring compression but also greater thrust (compare forces

I and II of Fig. 1452); conversely for a convex external outline the ring compression is reduced, which may even become ring tension, and accordingly the thrust on the abutment is accordingly less (compare forces III and I in Fig. 1452). The concave spire on account of the greater ring compression has more ability to resist unsymmetrical loading, and conversely the convex spire exerts a smaller thrust on the abutment. Thus it depends on existing circumstances, which of the two deserves preference in a given case.

Even ogee spires may be erected (Figs. 1453, 1454). The direction of the pressure on the abutment also here again coincides with the lower tangent, and thus the thrust in Fig. 1453 will be greater than in 1454. The ring stress at the different heights depends on the course of the curvature; it is quite possible to build spires in the forms of Figs. 1453 and 1454 without ring tension occurring at any height, the outline must show not too strong a curvature outward and nowhere approach too nearly the vertical. Forms like Fig. 1455 on the contrary will have ring tension along the considerable distance a b, but since this is avoided as much as possible in masonry, such spires or domes a are opposed to the requirements of masonry construction; only by special expedients or a waste of masses, while the interior is increased to form a true dome (see right side of Fig. 1455) can it be made permanent. Domes may be so formed that the ring stress shall everywhere be 0 (see p. 55 and Fig. 126), yet domes to be preferred have ring compression.

Calculation of thrust and ring stress of any domes.

Since then ring tension in masonry is avoided as much as possible, the calculation readily gives an account of ring compression, and it is important to learn a simple procedure by means of which the magnitude of the ring stress is to be found in any dome at any height (Fig. 1456).

With the assumption that the ring stress takes care of this, that the longitudinal compression everywhere approximately passes in the direction of the tangent downward, at the point to be examined is cut out by horizontal planes I-I and II-II' a not too high ring. The inclination of the tangent at the height I-I is termed a_1, that at the height II-II being a_2, and just as for the cone (p. 605) the thrust in the entire circumference at the height I-I is; $H_1 = G_1 \cot a_1$, and at the height II-II is;

$H_2 = G_2 \cot a_2$. The thrust H_d produced by the joining of the ring is the difference between H_1 and H_2; $H_d = G_1 \cot a_1 - G_2 \cot a_2$.

So long as this H_d remains positive, ring compression exists, but when it is negative, ring tension occurs. But the magnitude of the ring stress is easily found by the formula:- $U = \frac{H_d}{2\pi}$.

These relations are true for any outline of the dome, even when within the ring appears a break turned out or in. The lower the ring is taken, the more accurate is the result, yet one need not be too careful about this, and for high domes may generally cut out without hesitation rings 1 m high without injury to the accuracy usually required.

For domes with polygonal plans apply the same relations with the consideration of the little variations and the angle of inclination already treated. The horizontal thrust for the entire circumstance is again $H = G \cot a$, when G is the total weight of the dome, and the ring stress is found as just shown by the difference H_d of the thrusts, but where according to circumstances its magnitude lies between $U = \frac{H_d}{2\pi}$ and $U = \frac{H_d}{n\ 2 \sin \beta}$, (n is the number of sides of the polygon, and β is half the angle at the centre for one side). By all this is it shown that the calculation of masonry cones, pyramids and domes with sufficient accuracy for practice belongs to the simplest problems.

7. Wooden spires of towers.

Wooden spires of masonry towers.

The defects and difficulties mentioned above that are connected with the construction of masonry spires in brickwork may have led to the so frequently occurring wooden spires covered with slates or metal, in regions where brickwork is native, as well as the fact that not all stone is able to resist the injuries of weathering in the exposed position of the spires. Both reasons may continue in the present, but the advantage of economy, that was peculiar to the wooden spires in the middle ages, no longer exists in modern times, but it is rather the contrary in countries that furnish stone of sufficiently good quality, even when men would make the walls of the belfry thinner with regard to the entire removal of all thrust by the wooden spire, that is however possible in only a slight degree (p. 627).

Inclination.

The advantages of seep inclination mentioned above also continue for the wooden spire in more than one respect, and therefore

they have the same proportions as the stone spires, and indeed in the later periods of the middle ages there were favored almost too slender forms for wooden spires. Therefore we mention the spire of the church in Wetter dating from the first part of the 16 th century, which shows the proportions of 1 : 8 1/2.

Requirements for the woodwork.

In the construction of wooden spires, three points are chiefly to be kept in mind.

1. The arrangement of immovable base and neutralization of t the thrust of the rafters.

2. Security against overturning.

3. Stiffening the wooden walls against any bending, turning etc.. The fastenings of the woodwork that must fulfil these different requirements may be stated, assuming an octagonal ground form.

a. In the direction of the diagonal of the octagon.

b. In the direction of a cross inscribed in the octagon. Fig. 1458

c. In the direction of the sides of the polygon.

Base of the spire.

If we first take the direction for the base, there results f for a a framework of timbers running diagonally to receive the rafters and struts (Fig. 1457). At most two diagonal timbers may extend through and be halved together at the middle, and t the others must be placed against cross beams, and for strengthening it is best to place two timbers beside each other for the continuous diagonals. The jack beams must be connected to resist tension to receive the thrust of the rafters.

For b results the layer of timbers shown in Fig. 1458.

For c then by avoiding all through timbers occurs an immovable series composed of wall plates halved at the angles (Fig. 1459), on which are fixed the beams to receive the rafters and struts. If such an octagonal series lies on the walls of the square tower (Fig. 1459, right), then the wall plates at the four corners may be supported by corbelled masonry or brackets, but this is generally unnecessary and a free bearing of the short timbers is permissible.

If we now consider the thrust of the rafters and struts as a analogous to the thrust of the vault, the resistance of the abutments is here replaced by tiebeams (Figs. 1457, 1458), or by a series of anchors (Fig. 1459). The series of wall plates is

also very useful as a basis for the tension framework. (Fig. 1457). If the thrust of the rafters is certainly neutralized, at mose can come in juestion still merely a sliding of the entire base (by wind), which is made almost impossible by the friction of the wood on the masonry, even if no anchoring exists, but on the contrary it is not excluded that with mortar still soft, a violent storm may slide the upper courses of masonry and the spire.

To ensure the spire against overturning must serve its own weight or if necessary an anchoring to the masonry.

To prevent the hip and jack rafters from bending, and generally to make impossible any moving and crushing of the sides of the spire, struts and purlins must be inserted, which may again lie in one of the three directions (Figs 1457 to 1459).

Diagonal bracing.

The bracing corresponding to Fig. 1457 first consists of 4 X-braces placed over the diagonals (Fig. 1460), each of which is halved on an opposite rafter. These X-braces are so arranged as to cross each other at the middle, and they are repeated two or three times in the height of the spire. Above the last crossing then the stem of the spire, that is joined by the angle rafters with mortise and tenon, like the ribs of a vault at the keystone. The stem of the spire then rises above the junction of the rafters and bears the cross crowning the spire. Further the X-braces are also often replaced by collar beams and girts. For great s spires, the angle rafters can also be strengthened by parallel struts directly under them or separated by a space, into which the X-braces are also halved.

Stiffening by crossed beams.

The second direction of the connection is such that the braces just described do not lie in the diagonal planes, but in the p planes of the cross (Fig. 1458). Instead of these there may be placed at certain divisions of the height of the spire (3 to 5 m) timbers crossed as in Fig. 1458, so that the separate beams strike the angle rafters. For more secure support of the timbers and for better stiffening are then added braces (Fig. 1462).

The second layer of beams strike the angle rafters at the points a and a′, the third at the points b and b′. The point a is supported by the strut s, which is halved to the brace x, so t that it later secures also the point p of the same timber. On

the timbers a a to those parallel are laid the two timbers f f (or f″), which again bear the girts g and g″. The latter then receive the construction consisting of the timbers b b and b′b′ consisting of a part of a brace, which is repeated upward until the narrowing of the spire prescribes a different and simpler system of construction composed merely of girts.

Close beneath the apex the timbers of the cross-shaped framework (after Fig. 1458) are so close together, that they serve to clamp between them the stem of the spire carried down far , (also termed the king piece, and thus hold it secure.

Bracing in the planes of the sides.

The third bracing lies in the direction of the sides and consists in this, that at certain distances determined according to the dimensions of the rafters, at distances in height amounting to 3 or 4 m (Fig. 1462), there are formed horizontal bands consisting of 8 pieces, that join the angles at a, b, etc., and are each supported by 4 X-braces c, d, alternating in the sides. It is evident from Fig. 1462, that the X-braces are placed parallel to the plane of the wall of the spire, and its external surface lies inside the inner edges of the rafters, and that t the fall of each cross inward, i.e., that of the lower c is resisted by the girt of the cross starting thereon like d.

Likewise here is it useful to double the angle rafters (Fig. 1463) where the inner is separated from the outer by a space a and connected together by ties z. The construction just described of the X-braces then stands under the inner struts. The ties become girts for the support of the jack rafters, and by an extension of the ties outside (a in Fig. 1463) passages with balustrades can be formed, just as between the internal struts and the walls of the spire exist internal passages. When the struts are placed directly beneath or with a very small interval under the hip rafters, then the girts and cross lie between them, and thus produce particularly strong connections ob all parts. There is certainly to be taken care to avoid any bending inward of t the angle timbers, either by flexure of the hip rafters by means of ties or bolts, or by a corresponding layer of beams above each series of girts, since otherwise the ascent of the spire will frequently be made.

Space is lacking here for us to give an entire development of certain constructions, which are therefore not given at length.

For example there are sometimes found instead of the eight internal struts (Fig. 1463) but four (Fig. 1464), which rise as in the lower part of the spire as a frustum of a pyramid, and serve for a safer placing of the crossed or even also the diagonal b braces. They are particularly suitable when wide and narrow sides of the spire alternate as on the south tower at Jerichow.

Concerning the connections of the timbers it may only be stated, that at the crossings to avoid deeply cut halving, the timbers do not lie in one plane, but only lose a part of the dimensions. The ends of the timbers are allowed to project, where space permits; where this is impossible, it is preferred to use the halving represented in Figs. 1465 and 1465 a instead of the usual concealed tenon.

The wooden framework of the spire thus formed is then covered on the outside by nailed sheathing on laths, which receives the covering.

Covering of the roof.

By the use of slates is obtained a decoration of the surfaces by patterns with slates of different colors, but less effectively only by the mode of laying. Securing the angles of tne hips is most simply produced by overlapping of the covering on one side beyond the other, better by a variation of the mode of covering the surfaces, about so that on each side of the angle extends a separate row of slates, that is either the French or German mode of covering the surfaces (Fig. 1395). But the best security for the angles results from strips of lead fastened o over the slates, which essentially contributes to the animation of the whole, particularly if them are ornamented by lead crockets in relief. Durability and also the external ornamentation of the spire is enhanced by a lead covering, whose sheets run horizontally, or are laid in an oblique direction on many French towers and thereby form a pattern.

Covering and crowning the stem of the spire.

At the base of the pointed ending of the stem of the spire a are placed iron bars in the form of an inserted V, so tnat the branches extend down on the wood and are fastened there by nails or better by iron rings placed around over them. (Fig. 1666). These rods there form the vertical branch of the crown. For larger dimensions four iron bars are fastened on the stem of the spire, which are then clamped around this directly placed vert-

vertical iron rod and connected with it by indents as well as by rivets and rings. The apex of the spire on account of the small dimensions of the surfaces no longer permitting the placing of separate slates, and also to make the joint between slates and iron tight, is covered by lead or copper.

This metal covering is terminated by a lenticular knob, which is likewise of lead or copper and is indeed hammered up, so that it consists of two halves a and b (Fig. 1466). This knob is then attached to the iron rod, best under a wrought projection on the same (c in Fig. 1466). The lightness of the effect can be enhanced by extending the rod of the spire beyond the mathematical apex of the pyramid, and the ornamentation of the whole by a r richer treatment of the lead covering, of the knob as well as of the ironwork of the cross.

Very helpful here is the easy hammering of the lead in relief, by means of which the knob may assume similarly rich forms as in stone (Figs. 1093 to 1095), or merely in such an extremely characteristic mode of treating the metal, it is best by separate spherical and prismatic projections, whose outer openings are closed by a soldered sheet of lead (Fig. 1467).

It further makes possible richer crowning by leaves or buds after the style of the crossflower, by the placing of a second lead cap above the knob (Fig. 1468) to which are soldered the separate leaves of the crown. The leaves are cut from lead sheets as developed, and then bent according to their relief. The lead covering of the stem of the spire may likewise be ornamented below the knob by crockets soldered to the angles (Fig. 1473). As stated, the ornament of the crockets can be carried down on the lead coverings of the hips of the spire.

Smaller crownings are satisfied by a knob or the first described form of crossflower, where the stem of the spire or the iron rod fixed on it ends beneath the covering made by the terminal knob (k in Fig. 1468). Yet as a rule the latter is still far exceeded by the cross.

Cross and weathercock.

Also the ironwork of the cross is capable of the richest ornamentation and contributes essentially to the impression of the whole. We note before all other matters, that the cross is entirely wrought and never cast, and must generally bear a cock on its apex. Contrary to this the very frequent combination on old

works of the cross and weathercock is never to be employed.

The ornamentation of the cross consists in a finer forging of its ends, in the varied treatment of the angle bands that connect the arms, and for greater height in the addition of two or four iron scrolls riveted to the foot of the cross or fastened by iron rings and projecting far outward (Fig. 1469), whose ends are again forged into leaf or flower forms or are connected with them. Small towers are often contented with wrought scroll crownings without the cross. The iron rod has recently been usually utilized for the addition of a lightning rod, as also for stone spires.

Dormers.

The access necessary to the outer surfaces of the spire requires the repeated arrangement of dormers, which at the same time substantially contribute to the animation of the tower. In the simplest shape these form little gable roofs projecting on corbels, whose woodwork is entirely covered by slate or lead (Fig. 1470). The effect of this gable hood is substantially increased by a middle part that rises beyond the apex of the gable like the stem of the spire, or by the placing of actual spires which usually form the sole roof of the dormer, when two or three sides of the polygon projected over its front (Fig. 1471), thereby forming little turrets, that grow out of the great spire. A peculiarly treated example of this kind is formed by the spire of the Teyn church in Prague, that on four sides exhibits little hexagonal corbelled turrets about like Fig. 1472.

Passages and intermediate stories.

Likewise on wooden spires may be formed horizontal divisions of the spire either by external passages or by an intermediate story with vertical walls interrupting the inclination. The latter are placed over the face of the lower part of the spire, are projected outward, or also are recessed, so that the upper surface of the spire falls in the line of the lower. The external passages are formed b: projecting beams supported by plates and extending out according to the desired projection of the balustrade, receiving the floor of the passage and sometimes bearing a parapet above which rise pinnacles, whereby however the pinnacles must be connected above the rafters of the upper wall of the spire (Fig. 1463). The intermediate story, of which the towersof Notre Dame at Chalons furnish a particularly rich exam-

example, easily result from that construction of the spire mentioned on p 616 with doubled angle rafters (Fig. 1477).

Simple roofs of towers.

Wood construction further leads to certain other forms of towers more nearly corresponding to ordinary roofs, whose character is peculiar to more secular works, yet for limited means may also be employed for churches; they lead to great diversity and in any case deserve preference over the later experiments, the retaining of the typical form of spire with a squat low shape, making possible a resulting economy. There belong here:--

1. The ordinary gable roofs with stone and even with wooden gables, the latter allowing the wood construction to be seen, which for protection from the weather can be slated. The middle of the roof or the front apex of the gable are especially marked, the first by a roof turret and the latter like the dormers of the spire, by a king post rising above the junction of the rafters and receiving the cross or weathercock .

2. These roofs are almost more common than gable roofs, chiefly in the form shown in Fig. 1474, where by different inclinations of the suffaces may be obtained any desired length of ridge even on a square plan. But such roofs may also be constructed on a polygonal plan, whereby the lengths of the sides mostly determine the length of the ridge. When one is also inclined to regard this so frequently occurring form of roof as an expedient, that must replace the spire omitted from lack of means, then s sometimes by the addition of a roof turret may be given to the whole the impression intended at first. Fig. 1474 exhibits a r richer example of this kind from the tower in Champagne with angle turrets over the buttresses.

3. The intersecting gable roofs are mostly connected with a roof with turrets placed over the middle, also sometimes with a slender spire or finally with a strongly elevated middle post bearing the cross and weathervane, against which abut the four hip rafters.

Roof turrets.

By roof turrets are understood little towers, that instead of being placed on masonry or a visible wall, are supported by wooden construction under the surface of the roof from which they rise, appearing as a rule to stand astride the ridge (Fig. 1475). Its ground form may be square, hexagonal or octagonal. In sect-

sectional construction are chiefly to be distinguished two kinds. For either the spire of the turret is separated by a formel cornice from the story beneath it with vertical walls (Fig. 1478), or its angle parts are directly continued in the rafters of the spire (Fig. 1479), so that strictly taken it is treated merely as a spire extending through the roof, and the proper tower story is only indicated by the penetration of the lower part and the decoration. An examole of the last kind is formed by the roof turret of the cathedral of Paris, which was erected by Viollet-le-Duc and is to be regarded as an unexcelled model in every respect (Dict. Vol. V, p. 454). It differs from the others in that the proper bracing that transfers the weight to the crossing piers at least partly rises above the roof. When the weight of the roof turret cannot well be transferred by trasses to the outer walls or the crossing piers, then in case it is not too great, it may be placed on long radiating or parallel sills, that distribute its weight over as many beams as possible. Very light roof turrets may even be borne by a well supported collar beam.

Roof turrets as a rule are entirely slated on the simpler works, and only the ends of the stem of the spire rising above the spire or gable are covered by lead. An example of this kind from the church S. Maria in Marburg is shown in Fig. 1476. Richer f forms result with an entire covering of lead, and in such manner can be attained a magnificence not inferior to that of developed stone construction, even surpassing it in at least a visible boldness. As peculiarly splendid examplesbesides the previously mentioned new roof turret in Paris, are also to be mentioned thuse belonging to the 14 th and 15 th centuries church of the Minorites in Cologne and the cathedral of Amiens.

8. Stresses in wooden spires.

Wooden spires are statically so nearly allied to stone spires, that the formulas deduced for the latter may also be scarcely changed and retain their value here. An essential difference is only to be seen in this, that the tensile resistance of the wood can be utilized, which is particularly manifested in the possibility of easily neutralizing the thrust in the ends of rafters without the aid of abutment walls.

Instead of a repetition of what was stated for stone spires, an example may serve here instead of further explanations.

Example. The dimensions of the timbers of a great spire covered by slate are to be calculated, that including all structural parts weighs 120 kil per sq. m of its surface, and that for 10 m width of base measures 40 m in height of side (measured on t the inclination).

Since the side of an octagon 10 m wide measures 4.15 m, each surface of the spire has an area of $\frac{1}{2} \times 4.15 \times 40 = 83$ sq. m, which corresponds to a weight of $83 \times 120 = 10{,}000$ kil in round numbers, so that the entire spire weighs 80,000 kil.

Neutralization of the thrust.

Thrust at the supports. The thrust at the entire perimeter is G cot a. (p. 610). The angle a of inclination of the side is 82.9°, of the hip is 82.3°; for both it is sufficiently accurate to place cot a = 0.13, so that the total thrust = G cot a = $0.13 \times 80{,}000 = 10{,}400$ kil. It will be assumed that besides the eight hip rafters, there are 3 jack rafters in each side, thus being 32 rafter is all, each of which rests on a tiebeam, and each of the latter with uniform loading has a thrust of $\frac{10400}{32} = 325$ kil. If the thrust came at the angles alone, each of the eight beams in Fig. 1457 would have a tensile stress lengthwise of $\frac{10400}{8} = 1300$ kil. (In the cross-shaped beams in Fig. 1458 would be about the same). Since 1 sq. cm of the cross section of wood may be stressed by about 80 kil tension, there would result a cross section of $\frac{1300}{80} = 17$ sq. cm in round numbers, thus a small strip 4 × 4 cm would suffice; for flatter spires would be required s somewhat greater values, and even smaller for steeper spires. It is evident that the dimensions of the tiebeams are less important than a sufficiently reliable fastening of the ends, especially at the joints and crossings of the tiebeams. In spite of the small forces, this point must not be neglected, for otherwise even the tiebeams transfer the thrust of the rafters by means of their friction to the masonry, which it is desired to avoid. (Although the walls are strong enough in many cases to receive the thrust.

More permissible is always the neutralization of the thrust by a series of doubled wall plates (Fig. 1459), even if a tie or cross framework is found over them. The tension in this series according to p. 605, 611, is:-

$$U = \frac{G \cot a}{8 \times 2 \times \sin 22\frac{1}{2}^\circ} = \frac{80000 \times 0.13}{16 \times 0.38} = 1700 \text{ kil in round numbers.}$$

If for safety it is assumed that one of the wall plates, indeed

the inner, is sufficiently strong to receive this tension, then is required a cross section of $\frac{1700}{80}$ = 22 sq. cm, thus dimensions of $5 \times 4\frac{1}{2}$ cm. But since it is usual to give wall plates a four-fold to eightfol cross section, full security exists, if they are only in a measure fastened together by tenoning or halving, and if the position of the fibres in the two series is suffociently long not to be sheared. Taking the resistance of the wood to shear in the direction of the fibres at only 10 or even 5 kil, then with 12 cm breadth of the plate only $\frac{1700}{10 \times 12}$ = 14 cm to $\frac{1700}{5 \times 12}$ = 28 cm length of fibres, i.e., 14 to 28 cm distance between the the two planks would be required. Besides at the c crossings the through wooden pins would do their work.

Safety against overturn by wind.

Overturning by wind. If it be assumed that the wind acts with full pressure on the triangular vertical section 10 m wide and about 40 m high, overturning would follow if the overturning m moment $W_o \times 10 \times \frac{40}{3} \times \frac{40}{2}$ were equal to or greater than the resistance moment ; which would be 80000 × 5.0 for a wind pressure W_o = 150 kil per sq. m. If the oblique action of the wind on t the side were considered, its effect would be only 0.707 times as much, and then overturning would only result for a wind pressure of 210 kil per sq. m. Since the maximum wind pressure observed in Europe amounts to about 200 kil per sq. m, then the s stability would suffice, but still a slight anchoring of the 8 hip rafters to the masonry can be recommended. This would certainly be necessary for lighter towers.

In order to show how the dimensions of the anchors may be calculated for the case, that this spire with metal covering and extremely light woodwork weighs only 60 kil per sq. m, thus 40000 kil for the whole, and that it must resist a wind pressure of 200 kil per sq. m on the full vertical section. It may then be further assumed that only the two wall anchors farthest from t the pivot edge, about 9.5 m distant from it, shall act. If Z = tensile stress in one anchor, then by equating resisting and overturning moments:-

$$2 Z \times 9.5 + 40000 \times 5 = 200 \times 10 \times \frac{40 \times 40}{2 \times 3} .$$

Hence Z is computed to be 17500 kil, i.e., each vertical rod with a stress of 1000 kil per sq. cm must have a cross section of 17.5 sq. cm, and be carried down so deeply that its lower p plate shall be loaded with 17500 kil or 7 to 10 cu m of masonry

according to weight. Since the anchors at the other angles assist, even if in the second line, the anchors could be made somewhat lighter; generally will seldom occur such great danger of overturning, since spires of such great size would be heavier. Yet the example must show how important the anmhoring may become in certain cases. In the middle ages it was usually effected by extending the correspondingly connected timbers one story below.

Compression in rafters.

Stress in rafters and struts. According to p 604, 611, there acts longitudinally in the entire length of the rafters a compression $\frac{G}{\sin a}$, thus here $= \frac{80000}{0.99} = 81{,}000$ kil. In each of the 32 rafters would average about 2500 kil, or if the 8 hip rafters alone receive the compression, there would be on each 10,100 kil; with 6o kil compression would be required 170 sq. cm or 10 × 17 cm. On account of the danger of buckling in consequence of the great free length, and especially by the increase of the compression by the wind, larger dimensions are necessary.

The most unfavorable stress would occur from wind, if the spire were ready to fall and its entire weight rested on the two hip rafters or angle posts at the pivot edge. Each of these timbers must then support 40,000 kil, and thus with an allowance of 60 kil it would require 666 sq. cm or be about $22\frac{1}{2}$ × 30 cm in cross section. With proper struts buckling could only be possible in the free length between each two girts, but with such large timbers and girts not too far apart (3 to 4 m), it could scarcely come in question; conclusions concerning this would be given by the formula given on p 494, in which is to be inserted for wood:- s = 10 and E = 100,000 (for wrought iron s = 5 or 6, E = 2,000,000). For such great spires instead of such very heavy hip rafters might well be employed only moderately large rafters with a strong corner strut underneath (Fig. 1463). The calculated dimensions could be somewhat reduced with regard to the aid of the other jack rafters, especially for anchored spires, so that it could be regarded as sufficient to make the bearing hip rafters and struts; for spires 8 to 10 m wide about 20 × 25 cm, for 6 to 8 m wide, 18 × 20, to 18 × 23 cm, for 4 to 6 m wide, 16 × 18 to 16 × 20 cm. In this proportion can also be reduced the dimensions upward, which makes it much easier to obtain long timbers.

Jack rafters with 3 to 5 m between their supports only require

to be made as large as the ordinary rafters of roofs, to provide for flexure by weight of covering and wind pressure.

Ring compression. Except for the effect of the wind, the compression in the ring is very small, and is computed (p 611) by the formula:-- $U = \frac{g \cot a}{6.123}$. If the first ring above the base is about 9 m wide and the distance between rings is 4 m, there belongs to this ring a horizontal portion of the tower of about 120 sq. m area, which for 120 kil per sq. m has a total weight g of 14,400 kil. Since cot a = 0.13, thus there results a compression in the ring timbers of $U = \frac{14400 \times 0.13}{6.123} = 306$ kil. With regard to the wind, it is well to make the ring timbers strong enough, that in the most unfavorable case half the wind pressure acting on the corresponding part can be transferred. The part of the height corresponding to the lower ring presents to the wind a surface of about 4 × 9 m = 36 sq. m. Id the wind pressure is taken at 200 kil per sq. m, or on account of the somewhat oblique direction it is taken at only 0.707 × 200 = 141 kil in o calculation; thus it amounts to 5200 kil in round numbers, thus producing 2600 kil compression in the ring timber. Hence a cross section of $\frac{2600}{60} = 43$ sq. cm or 6 × 8 cm, but on account of the danger of buckling (see above), with a free length of 3.6 m, 15 × 15 cm is to be employed. Since the upper rings are stressed far less, the usual dimensions of timbers are always sufficient; a good connection at the angles suitable for transmission of a small tension is also here of more importance than great dimensions of timbers.

Stresses in the struts.

Wind struts. For the sole action of its own weight the spire can be built with small rafters and girts. The effect of wind, as we have seen, compels these timbers not only to have larger dimensions, but also requires other struts, which according to Figs. 1460 to 1463 may lie in the interior of the spire or in its enclosing surface.

The X-braces in the surface (Fig. 1462) have to prevent all bending and distortion of the surface; the maximum stress in the X-brace must occur when it is required to transfer alone to the nearest hip the entire wind pressure calculated for the girt, thus being for the lower panel 2600 kil. On account of the inclination, which may amount to 45° in the lower panel, this pressure is increased by the corresponding resolution of forces, in

the proportion of $\frac{2600}{\sin 45^\circ} = \frac{2600}{.707}$ = about 3700 kil. On account of the great length which may be fully 5 m, the danger of buckling also increases, so that according to the formula for buckling (see above and p 494), a cross section of about 19 × 19 cm is computed. If the braces are firmly fastened at their crossing without too much weakening, the danger of buckling is reduced if the ends are also firmly fastened against tension (Fig. 1465), and then the countrebrace may act to relieve by its resistance to tension. Therefore dimensions of 16 × 20 cm abundantly suffice, and they may be made smaller in the upper portion and on smaller towers.

It is a defect that the X-braces in the upper portion of the tower are very steep and thereby lose much of their effect.If they have there only a lesser importance, then it may be preferable in many cases to set them with their ends not against the girts, in a somewhat flatter direction directly tenoned into t the hip rafters or struts. Thereby will also be avoided the interfenence with the cross grain of the girts. If the X-braces alternate in the panels up to 2/3 the height, then crushing can occur only by shrinkage of the timbers and loosening of the connections, for example under the effect of the wind the polygonal plan may be flattened somewhat at the mid-height of the tower. To prevent this the X-braces can be employed above certain or all girts (Fig. 1458), but not as usual be placed between the girts, but tenoned into them and then tenoned sidewise into the hip rafters or struts. Some horizontal beams are further desirable for ascending. It is further noted that also the board sheathing with two nails in the end of each board forms a very efficient wind bracing, that fully replaces the X-braces in the upper part of the tower.

Bracing as in Fig. 1460 has the advantage, that it connects the hips struck by the wind directly with those lying opposite, but on account of their great length they bend easily under compression, and it may therefore be recommended to transfer the compression by timbers, while the oblique timbers then become tension members.

When the bracing is incomplete, then aside from destruction by wind or injurn to the covering by strong flexure, a gradual change of form of the spire occurs. The hygroscopic variations in the timbers, the repeated wind stresses in one side, and the

varied warming by the sun's rays may act together to produce c curvatures and even twisting of the entire spire, as such occurred in a very surprising manner on the towers at Gelnhausen.

Iron spires.

Iron spires of towers are likewise constructed as in Fig. 1462 with rafters, girts and X-bracer; the latter are in tension while rafters and girts are in compression. The calculation of i iron towers, which are combined with small use of material with very ornamental sections, can be carried out with sufficient a accuracy in the manner previously described.

9. Stresses in the walls of towers.

Compressile stresses due to their own weight.

For towers their own weight, the thrust of the masonry spire and vaults with the wind pressure come in consideration.

Prismatic and pyramidal structures.

For the considerable height of towers, the compression under their own weight plays a very important part and even draws very narrow limits in case of rather weak materials. If it is desired to erect walls of uniform thickness or prismatic piers with tamped clay or lean lime concrete, that weights 1500 kil per cu. m and to which can be applied a compression of only 2 kil per sq. cm, the permissible height would be calculated as follows. A cube of 1 m side would load the area of 10,000 sq. cm with 1500 kil, thus with $\frac{1500}{10000} = 0.15$ kil per sq. cm. For each additional cube pladed on this, the compression would be increased by 0.15 kil; then to reach the allowable compression of 2 kil per sq. cm, only $\frac{2.00}{0.15} = 13\frac{1}{3}$ cubes could be placed, i.e., on the ground form, a vertical wall of this material could be built only 13 1/3 m in height.

In like manner brick masonry weighing 1600 kil per cu. m and with 7.5 kil per sq. cm allowable compression would be stable f for a height up to $\frac{7.5 \times 10000}{1600} = 47$ m in round numbers.

Likewise for hard bricks or clinkers weighing 2000 kil per cu. m and for 15 kil per sq. cm maximum safe compression, masonry might be built to a height of $\frac{15 \times 10000}{2000} = 75$ m; for cut stone weighing 2600 kil per cu. m and a compression of 30 kil per sq. cm $\frac{30 \times 10000}{2600} = 115$ m.

If weights of ceilings, etc., are added to this, the permissible heights would be reduced, and the same is the case if compression by thrusts of vaults or by wind is excentric, the com-

compression at one edge being thereby increased.

Accordingly this has the appearance that the heights of buildings of our ordinary materials had quite narrow limits, yet t this is not so, for by skilful distribution of the masses it m may far exceed the values obtained. For example if the thickness of a vertical wall be gradually reduced to 0, it may be built twice as high as for uniform thickness, and the same is the case for a hollow pyramid or a hollow cone with constant weight of covering. But if a tower be in the form of a solid pyramid or even of a hollow pyramid with thickness of walls uniformly decreasing upward, even a threefold height is conceivable, and thus for the assumptions above; for brick masonry 140 m, for clinkers and for cut stone 345 m.

These advantages did not escape the ancient masters, the Egyptians already erected their highest structures in form of pyramids, but built them almost solid, thus creating masses of stone that appear shockingly stumpy in contrast to the wonderfully light towers of the Gothic. The latter not only approximated in the main forms the advantageous form of the hollow pyramid, but even went beyond this in the suitability of the distribution of the masses, which was possible in the structures following later. Thus all further requirements such as covering the interiors, resolution of the solid walls into separate bearing piers, bracing against overturning by wind, etc., were so masterly combined together, and at the same time the stamp of an art work of such perfect form was impressed, that only the highest astonishment can be realized by works like the towers of Cologne cathedral considered from this point of view. If one considers how far is the distance from the vertically ascending tower of the Early Christian and Early Romanesque towers with their scarcely diminished thickness of walls to this statical creation well weighed in all directions, then must one be astonished by the lightness with which the old masters attained this aim.

Best distribution of the masses.

We stated that men could make possible a more suitable distribution of masses than that of the pyramids; in fact men not only could do this, but theoretically it is even conceivable to erect an infinitely high structure without the compression at the base exceeding a fixed value. There the upper parts certainly are r rapidly reduced to such small thickness, that the possibility

of construction and especially the danger of overturning very soon set a limit to the height.

The law here unavoidable, according to which a structure must be formed, that shows at each height the same compression per unit area is:-- log nat $(b_2 : b_1) = \gamma h : k$.

Herein b_2 and b_1 are the areas of any two horizontal sections (in sq. m), that are distant apart by h (in m). k is the allowable load (in kil per sq. m), and γ is the unit weight of the masonry (in kil per cu. m).

If it is assumed that two areas are cut out, where the b_2 is twice that of the upper b_1, then log nat $(b_2 : b_1)$ = log nat 2 = 0.69315. Inserting this in the preceding gives:- $0.69315 = \frac{\gamma h}{k}$, and from this follows $h = \frac{0.69315\ k}{\gamma}$. Accordingly for masonry of a given weight and a fixed permissible compression, one can calculate at what differences in height the ground area must be doubled. For example if we assume that the upper part of a tower of brickwork weighing 1600 kil per cu. m has been so designed, that it has a olad of $7\frac{1}{2}$ kil per sq. cm, thus being 75,000 kil per sq. m, and we wish to extend the tower downward without increasing the compression, we must gradually increase the ground area, so that at the depth $h = \frac{0.69315 \times 75000}{1600} = 32.5$ m, it has become twice as great. But again at 32.5 m must then the area again be doubled, thus being fourfold, etc., and likewise eightfold at the next division of the height, then sixteenfold, etc. This requirement for materials finally increases so rapidly downward, that a practical limit is soon drawn.

But in any case we see, that the heights given above for pyramids do not reach the extreme limit. For the clinker masonry mentioned with a weight of 2000 kil per cu. m, and 15 kil compression per sq. cm, thus 150,000 kil per sq. m, the ground area must be doubled at heights of $\frac{0.69315 \times 150000}{2000} = 52$ m, or for cut stone with a weight of 2600 kil per cu. m and 30 kil per sq. cm per sq. cm, $\frac{0.69315 \times 300000}{2600} = 80$ m. To erect towers of the last material 400 and 500 m high would not be so very difficult. By the help od granite or basalt, which has 1000 or even 2000 to 3000 kil ultimate resistance to crushing per sq. cm, it would be harmless to load them with 60 or even 100 kil per sq. cm or more, and it would be possible to reach such heights beside which our modern colossal towers like the Eiffel tower would seem like dwarfs. We see that our respectable cut stone need not longer

give place to iron.

We must here again oppose the erroneous view, that on account of the small resistance of mortar the strength of cut stone cannot be fully utilized. Certainly the resistance of concrete or poorly coursed rubble masonry depends almost entirely on the n nature of the mortar, but it is otherwise in brick masonry. Experiments in the technical experiment station at Berlin (Report of same in 1884, p. 80) gave for cubes 3 months old made of the same bricks in lime and cement mortars the slightly differing resistances of 44 and 63 kil, while the resistance of the kinds of mortar employed exhibited the great difference of 12.5 to 211 kil. For a longer time of hardening and thicker walls we judge that the difference in the masonry would be yet smaller. But for large ashlars and uniformly thin joints the influence of the mortar must almost enterely disappear, it being assumed that the latter has the otherwise required properties, that first consist in that it is pressed into the hollows without being entirely pressed out of the separate parts of the joints by the existing compression. Under these conditions would it be almost the same whether cement, lime, lead, chalk or powdered loam were employed, that selected good stones might fearlessly be used w with a loading up to 1/10 or at least 1/20 of the ultimate resistance to crushing, and thereby build considerably safer in any case, than if one now generally finds it well to stress easily rusting iron to 1/4 or even 1/3 its resistance (with connections that in part are no more trustworthy than mortar joints). Men have already made sufficiently bad experiments in the fall of numerous bridges.

We see from all this, that our buildings of weak materials and with disadvantageous distribution of the masses are restricted to very small heights, and that on the other hand by using good materials, the limits are drawn less by the resistance than by practical reasons of other kinds.

Stability against wind pressure.

Magnitude of wind pressure.

The stability of a body increases with its weight and its basal area, but on the contrary diminishes with the increase of the surface presented to the wind. Therefore it is important especially for the upper parts, which one seeks to construct as light as possible, that they be disigned with proper consideratiio of

wind pressure. Farther downward can the distribution of the masses be then made according to the laws previously given. The w wind pressure is greatest where it strikes a surface perpendicularly and is reduced considerably by a greater inclination of the surface, whether in elevation or plan (p 163). Thus the wind pressure against the angle of a square tower, in spite of t the greater diagonal width, is only 0.707 as great as the pressure against the side surface. The pressure against a cylinder is 0.785, that against an octagonal prism is 0.707 as much as the pressure against a perpendicular surface of equal area. S Since in determining these values friction on the surfaces was neglected, it is better to increase them somewhat, especially with large projections on the surfaces.

The magnitude of the wind pressure seldom goes beyond 120 kil per sq. m, but has occasionally been observed at about 200 kil in Europe. Where this concerns the calculation of stresses in roof construction or edge pressures in masonry, men are usually satisfied by assuming 120 kil per sq. m, especially in protected places. This is to be defended in so far that the strength of the material indeed is stressed only in certain limits, thus always retaining a certain safety. If it concerns lofty roofs or walls, it is advisable to increase this vaule under the circumstances to 150 or 180 kil. But quite otherwise are the conditions when the danger of overturning (for example of a wooden or iron tower spire not anchored), where no security exists to be counted upon; here for square structures must be taken at l least 250 kil for surfaces struck at right angles, for round or octagonal towers or spires at least 200 kil for the full vertical section. But if one desires to use smaller values like 120 kil, he must also introduce a certain safety and require that the moment of stability be at least twice the overturning moment.

Stability of towers.

If the stability is investigated by calculation, one must first be convinced that no direct danger of overturning exists (p 137); there one cannot usually be satisfied but must examine f for wood and iron, whether the members with wood support the structure just before the overthrow are sufficiently strong ((example on p 622), and for stone, whether the edge compression does not increase too much. For the last purpose is sought the point of intersection of the resultant pressure with the base

area (p. 140, 166, 336, 377) and then the edge compression is obtained according to p 141 to 145.

If the tower stands on separate very high piers, it may become necessary for these to be calculated particularly for overturning or bending (p 359 and p 169 above), but usually at corresponding heights the piers and even the walls of the tower are so strongly connected together, that the entire tower can be regarded as a connected mass. Then the basal area is regarded as a firmly connected figure, in spite of the fact that in some circumstances it is entirely resolved into separate piers.

To employ formula 5 on p 143, it is necessary to determine the moment of inertia for the ground plan, which is well known to be found for compound areas by addition or subtraction of the moments of inertia of the separate areas; for example for a circular ring, if D and d are the outer and inner diameters; $I = \frac{1}{64}(D^4 - d^4)$; for the hollow rectangle with outer sides B and H, inner sides b and h, is likewise $\frac{1}{12}(B H^3 - b h^3)$, etc. The kern of such a hollow figure is larger than that of a solid cross section and is calculated according to formula 4 on p 142. For example for the circular ring it is a circle with a diameter $= \frac{D^2 + d^2}{4\ D}$, and for the hollow square is a diagonal square with d diagonal $= \frac{B^2 + b^2}{3\ B}$; for the hollow octagon is an octagon with a diagonal $= 0.27 \frac{B^2 + b^2}{B}$. The thinner the thickness of the wall t the larger is the kern; in the limiting case that the wall is infinitely thin, D = d or B = b, consequently the width of the kern is $\frac{D}{2}$ or $\frac{2\ B}{3}$ or 0.54 B, i.e., twice as great as for the solid cross section. But that is very favorable, for the resulting compression in such hollow cross sections can be farther from the centre of gravity without too much increasing the edge pressure. Only when the compression in the hollow square with thin walls falls outside the middle 2/3, i.e., approaches the outer 1/6, the edege compression is doubled. But with regard to the increase of the edge pressure by wind or thrust and a vault, one must not fully utilize the permissible stress by its own weight, and a cut stone that can carry 30 kil, according to circumstances, will only be loaded with 20 or 24 kil by its own weight.

Towers with stone spires and internal vaults are to be so heavy that their stability is not endangered by wind, endeed it is usual in them not to increase much even the edge pressure. For towers with thin walls with wooden spires on the contrary the

wind exerts a substantial influence on the determination of the thickness of the walls. Care must be taken for these, that the wall struck by the wind does not bend, or considered as a straight arch does not press out the adjoining walls. Therefore not too thin are also made the walls of the towers without spires and the thrust of vaults.

Stability of spires.

When the masonry masses rapidly diminish upward, the investigation of the stability also extends to the higher plans, but must particularly take place for the spire. As already shown for the example on p 621, anchoring may very easily become necessary for wooden spires, without such spires presenting the full vertical sectional area calculated to resist the wind pressure of 200 kil per sq. m, if for a proportion of height of 2:1 it has a weight of at least 75 kil, or of 3 : 1 of 115 kil, for 4 : 1 of 160 kil, 5 : 1 of 200 kil, and for 6 : 1 of 240 kil p per sq. m of external surface.

For brick spires 1/2 brick thick occurs the danger of overturning with a proportion of height of 5 : 1 to 6 : 1, and the compression passes outside the kern for a 2 1/2 to 3 1/2 fold height; yet with sufficient safety can a spire 1/2 brick thick can be carried to about a fourfold height, if the apex is built solid, and attention is paid to the upper ending (p 597); for very heavy clinkers one can also go to 4 1/2 to1. Spires 1 brick thick permit doubled heights, and therefore do not require farther investigation.

Thrust of spires and vaults of towers.

Thrust of the spire.

If the possible neutralizing of the thrust of the spire by t the tensile resistance of the upper portion of the wall of the tower (p 606) is neglected, then must the wall be sufficiently strong to resist the thrust. The abutment is investigated for a square tower by taking an angle, thus 1/4 of the tower, or 1/8 for the octagon. If the abutment descends vertically, then must it have at top sufficient thickness or rather sufficient weight to quickly change the oblique force of the spore against the abutment into a steeper direction. On the contrary if this gradually extends outward or buttresses project from them, which are offseted downward, the mass of the abutment can be considerably reduced, indeed the more battering is its outer surface.

The limit would be for the tower walls to be inclined externally and internally to form continuations of the surfaces of the spire. The investigation of the abutment by calculation or graphically can present no difficulty, according to what is stated on abutments of vaults (p 122 to 153).

Thrust of vaults.

Since for vaults that occur in the interiors of towers, where very little thrust occurs at the angles (Fig. 366), and there the thickness of the abutments as shown by the Tables on p 150 to 152, even for vaults of infinite height, if the masonry be not crushed under its own weight, need not be excessively great, there is no reason for not placing the vaults in the upper part of the tower. The thicknesses of the buttresses given in the Tables mentioned could then be considerably reduced, when greater upper loads occur, but then by inclined position or even by corbelling the walls inward it is always easily possible to keep the line of support everywhere in the middle of the supporting parts without great cross sections of the masonry. To strive f for this and then by considering the wind pressure to increase the wall masses downward according to the principle of the increase of the load (p 624), those are the points to be kept in mind in designing towers. Very high towers can be built vern economically, but one can also waste masses of masonry in a very inexcusable way.

X. DECORATIVE PAINTING.

1. The colored Decoration of the Interior. (Note).

Note. Pages 629 to 637 are unchanged from the preceding edition.

Painting of certain parts.

Even in the last centuries and down to the present time have been made endeavors to change the original condition of Gothic churches by whitewashing or other ingenious methods, yet certain works in different regions remained in such preservation before such improvement, that from the principles according to which the middle ages proceeded in regard to coloring may at least partially be recognized. But a study of those principles is the more necessary, since on the point in question views are more widely divergent than on many others, and in each case it is just as difficult as essential to become freed from the last remains of modern habits.

We have frequently been engaged in the restoration of mediaeval churcher, in which the internal coloring was also to be restored, and in some cases have neither had the power or strength to avoid all the concessions to modern taste exacted from us. But we have thereby made the experiment, that only those works could in any way satisfy not us alone, but also the directors and thus the people, where the old was followed with all possible accuracy, and that in nearly all cases the concessions demanded were regretted by those who had required them. But we have had the experience on other works, in which it had been found well to depart from mediaeval types.

Plastering and whitewash.

The question of painting is connected with that of plastering or of whitewash. The last must occur everywhere that the material at command and the mode of execution thereby compelled makes it impossible to obtain even surfaces, and the simplest case of a coating thus requires a limewash, or where it is to create the ground for a richer decoration.

In both cases is the principle applicable, that the plastering as well as the coating must be an actual improvement. On rough walls of rubble it can be applied in its simplest form, while on a better material, first on such that makes it possible to secure even surfaces, the coating is only allowable with a view of a certain development of luxury, therefore requiring a richer treatment. Hence where only the window jambs, angles, mouldings

and the vault ribs are made of cut stone and the walls are of rubble, in the simplest case only the latter are plastered and colored, and the plastering adjoins the edges of the ashlars p projecting by the thickness of the plastering, which again remain uncolored, and where means permit, on the plastering will be painted even certain figure representations in entirely unsymmetrical positions. The latter result from the circumstance that such pictures are but seldom contained in the original plan, but arise from special courses or from vowed gifts..

Painting of keystones and compartments.

Likewise the limewashed surfaces of the compartments of rubble adjoin the ribs made of cut stone. Since now in the vaults the keystones already are emphasized by richer ornamentation in sculpture, it is nextat their greater distance from the eye to increase the effect of that ornamentation by color, this increasing their recognition as well as their splendor thereby. As a rule is there adorned not merely the sculpture of the lower surface but also the moulding bordering the edge of the keystone by gold and bright colors, and the same treatment is continued for a piece as the vault ribs and then cut off by radial bands. (Fig. 1, colored plate 147). The cause of this extension is not alone with the view of ensuring a wider field for the development of color, but also that it was first of all to find a suitable termination of this splendor of color on the member, which would not have resulted from the simple junction of the mouldings of the ribs left in the natural color of the stone to the richly painted keystone. In the church at Frankenberg all surfaces of walls and piers and further the capitals and ribs are left in their original dark stone color, but the keystones are painted in the mode indicated and are gilded, and an especially happy effect results because this splendor of color is carried by the ribs contrasting with the white compartments. Without this contrast, and particularly where the painting of the keystones differs but little in color from the rest and lighter parts rise from dark parts, will many modern restorations show how to produce a heavy and burdening impression.

In contrast to the plastered compartments the Frence mode of execution of the same in cut rubble described on p 109 permits an open appearance by its regular jointing. No less is this possible by a construction of the compartments in brickwork, and

indeed the effect gains life by the alternation of the color of the bricks with the stone of the ribs. In the arcades of the p palace of justice of Liege otherwise belonging to the Renaissance, the compartments are built with not the usual direction of the joints, but by the most varied interlacing of them are formed the most ornamental patterns, in a manner similar to the construction of the half timber work of the wooden houses of the peasants in the so-called old land near Homburg.

The effect of the compartments may even be increased by different colors of bricks, either by the alternation with glazed courses or by richer motives. But in every case is necessary a correct execution of the masonry of the compartment, the joints must extend through according to a system once adopted, and no lost courses may occur therein.

Painting of the capitals.

The next addition to the method of treatment before indicated then consists in a colored execution of the capital, which must extend to the mouldings of the abacus and astragal. Here are first possible two systems. The first would consist in this, t that only the ground of the bell should be more strongly distinguished from the foliage, generally by the decoration by color. The other would add thereto a further characterization of the ornamental details by varied coloring. According to the first would the ornament be entirely painted white or gilded and the bell would be colored dark (Fig. 7 on colored plate), or naturalism already makes itself felt by a green color of the ornament or by a dark green ground.

According to the second system would only similar parts be colored alike. Thus there results one color from the front sides of leaves, a second from the edge and back, the third from the stem, the fourth from the berries or flowers, and the fifth from the bell.

It is here self-evident that gold and even the original color of the material may participate as colors. An example of this kind from the church in Volksmarsen is shown by Fig. 5 of the colored plate.

But further a diversity not yet indicated in the ornament may first be produced by the coloring. Fig. 6 from the church in Wetter.

Painting of vault ribs.

The next step in advance consists in the entire coloring of the

vault ribs, yet where that special accenting of the keystones and adjacent parts of the ribs mentioned above can be retained, so that these are separated by richer painting and form glowing colors from the extension of the ribs.

As a general rule for the coloring of the latter may be applied, that the general effect must be either lighter or darker than that of the surfaces of the compartments, thus lighter with compartments of bricks not plastered, darker for limewashed compartments. This is especially true of the principal member of the ribs, this of the so-called pear-rib of the earlier, the flat hollows according to the later mouldings.

Then we have also here either a uniform coloring of the entire rib or a separation of the different mouldings of it by colors. Fig. 2 of the colored place gives an example of the former from the church in Wetter, and in regard to the latter, there can be extended to it the ground principle of heraldry, that c color can only adjoin metal, that never different colors of equal intensity, but only different tones of the same color may adjoin each other. Further the following principles are applied.

1. that the colors do not oppose the effect of the shadows, that in deep hollow be separated by light from a member like a round that receives much light.

2. That to obtain a bold effect the aid of absolute light, t thus of white or gold, and even that a decided dark, black or dark brown , is just as necessary as dark outlines and leads in glass painting, as well as transparent or white and yellow colors.

3. That the intensity of light or shade is in inverse proportion to the area of the space occupied. Thus a little round bears pure white or gold, a little bevel oh hollow pure black, while for those large and pointed rounds, Figs. 8 and 9 of the colored plate, as for larger hollows, both light and darg require s softening, which may either be by reducing the tone or by a pattern.

Reducing the tone is not so much by the addition of black and white as by the addition of another color, so that light becomes yellowish, greenish, reddish white, dark becomes dark slaty blue, dark reddish brown, greenish black.

The pattern substitutes alternation of colors or tones for the same colors in mixture. Therefore in the simplest case it is f found by radiating or inclined bands of different colors, for example of brown and white, green and white, black and yellow,

etc., so that also on that pointed round either the same colors abut against each other or are placed diagonally. They can further consist of triangles, cubes, scales, or bands, or panels enclosed by the different colors may be found for finer drawings. But such patterns must always be simple to be recognized, and before all must all imitation of relief be avoided.

Contrast of color is sometimes strengthened by black, lines separating bands, which are especially necessary if a color adjoins white. Such an example is shown by the pattern in three colors from S. Peter in Louvain. (Fig. 8 of colored plate.).

Bands may either be formed by a single color,or by several t tones of it and these tones then adjoin in straight lines or a are indented or intersect each other like flames. It is preferable there to separate the shaded bands by a single color or be formed of two strongly contrasting colors. For example if we assume green shaded bands, thhes are to be separated by a dark brown or white, or a white bordered red, brown or dark blue, or a black bordered yellow. Thus sometimes alternate shadings in several colors with such bands. Fig. 9 of the colored plate exhibits an example of the kind from the church in Volksmarsen.

What concerns the placing of the colors on the different members of the ribs is, that these are not always chosen with regard to a heightening of the contrast, but at least for richer mouldings, are usually formed by adjusted groups of them. Thus in Fig. 10 of the colored plate from the castle chapel at Marburg, a transition from the red flat to the white round is formed by the yellow, contrary to which the white round increases the separation between red and blue.

But further pure and gleaming colors areechiefly taken for c certain prominent points like keystones, while for all large areas are preferred reduced or mixed colors.

Especially for the red is indeed exceptionally employed pure vermilion, where the highest magnificence prevails, while its ordinary tone is darker and more like madded (burnt ochre, see below). If then time and dust can injure it, we still frequently have ornamental interior structures like tabernacles, where the original tone was not pure vermilion. Such a dark red tending to brown generally forms the local tone on those little internal architectural works, and it is then brightened by gold and blue, white or by green and white.

The original tone of blue is hard to recognize as a rule. In general it is determined that it must be lighter than the red. For this reason the artificial ultramarine cannot well be employed, which in its pure condition is too dark, but mixed with white becomes muddy. A shining blue is best represented by pure smalt. But an entirely different character has dark blue, which as in Fig. 6 of the colored plate may even tend to gray.

Likewise green varies much, sometimes shining and sometimes softened, in the first case represented by Schweinfurt green, in the latter by different mixtures of gold ochre with so-called green cinnabar.

Bands beside the ribs.

The effect of the ribs may further be heightened by a pattern band adjoining them and painted on the compartment, or be a simple band from which rise painted leaves, Fig. 11 of the colored plate, from the vestibule of S. Peter Jr. in Strasburg. The last motive recalls the crockets, and like them it is sometimes replaced by a comblike ornament, Fig. 12 from a painting in the c church at Wetter dating from the beginning of the 16 th century. From those separate leaves represented in Fig. 11 we then pass to the lower angle between the ribs and laso lying from the keystone on the surfaces of the compartments, soon treated more naturally,andsoon in the later plant and foliage forms in the style, to which we must return later below.

Painting the rounds and arcades.

From the painting of the vault ribs we further pass to that of the rounds. What has just been said of the larger members of the ribs is increasingly true of the always larger rounds, i.e., these either require simple and light tones, or a continuous pattern, which then on account of the lesser distance from the eye is to be executed here in a far richer manner than there. Striking examples of this kind are shown by certain French works in restoration, such as that at S. denis, of the S. Chapelle at Paris, and also of certain choir chapels in the cathedral of Amiens, Beauvais and S. Quentin, on which is seen the development of magnificence in generally the highest degree. It would partly lead too far and would be partly superfluous to go farther into the details of these works, especially since the publication of the S. Chapelle is well known generally, and those that have the luck to execute a portion of such a work would still

do well to make their studies at the place.

According to a painting of the rounds at least on the richer works, where the window occupies the full width of the bay, only the plain surfaces of the piers between the rounds and the ground of the arcades found below the windows remain. The latter in the S. Chapelle are covered by a painted blue tapestry w with gold ornaments, as then generally a tapestry pattern above without the folds there given is most suitable for this. In a chapel of the cathedral of Meaux is found a richer arrangement belonging to about the 15 th century. Likewise here a red tapestry pattern forms the ground, on which are painted a crucifix with Maria anf John at the sides, the Host above it and the chalice beneath are painted in the natural colors, so that the Host is at the apex of the arch. Beneath the chalice is then found a blue shield of arms with three white roses enclosed by green twigs, and below are two figures kneeling at prayer desks, the latter with the clothing of the figures terminating the entire representation at bottom.

The mode of treatment of the plain surfaces of the piers coincides with that around for the general painting of the interior, and in the simplest case consists of a rectangular pattern.

General painting of the interior.

What then concerns a general painting of the interior, those of the compartments, surfaces of walls and piers, there have come to us three different modes of this, but which naturally admit of endless variety.

First mode of treatment.

The first is chiefly found in the province of upper Hesse, t thus in the church at Wetter, the castle chapel at Merburg, and was found in the church of S. Elisabeth at Marburg before the restoration, and must be regarded as the original, belongong to the end of the 13 th or the beginning of the 14 th centuries, since it appeared on the two former works under the second one belonging to the end of the 15 th or beginning of the 16 th century.

This consists of a red local tone, which is tolerably intense in Wetter, and on which is painted a pattern imitating in white lines the jointing of regular masonry in courses about 22 to 28 cm high.

At the middle of each triangle of the compartments and enclo-

enclosed by the ribs is then found varied stars inclosed by circles, one of which is represented by Fig. 2b of the colored plate. The vault ribs are there colored with strong yellow ochre, the rounds in the dividing arches are white, the flat surfaces yellow and the hollows are dark reddish brown. In the transverse aisle the ribs are accompanied by narrow bands lying on the surfaces of the components with dark red leaves on a white ground. All surfaces of walls and piers are treated like the surfaces of the compartments, yet only the larger surfaces of the gable walls of the transepts are at both sides of the windows with two stars or rosettes like those just described, but richer and larger, painted in different richer patterns. The window mullions are colored dark reddish brown and lighted by white lines and dots, while in the angles of the window jambs are found white stones toothed into the red surface of the wall (Fig. 15).

By these different details are given indications, according to which the entire mode of treatment is in itself very simple, but can be devecoped to greater richness. Thus first by a general placing of that band accompanying the ribs on the compartments, either white or very dark, the stars, rosettes or smaller branches painted on the flat surfaces of the ribs and arch members, and further by the formation of panels with white grounds in the lower angles, between the ribs as well as first on the keystones with ornaments painted in the dark ground color, as also by the use of some motive on certain parts of the surface of the wall, or even by white ornaments painted at the same places on the red ground. To this was added even a richer treatment of the window jambs and angles, either in the style of the band accompanying the ribs, or by foliage executed with black outlines. To this was also added a rich treatment of the keystones and capitals executed in gold and pure colors, which also remained red and white in Wetter, as well as the arrangement of painted arched friezes below the windows, which must be kept entirely simple, without by any means similating an effect in relief.

The second system of treatment by color differs from the former only in that the coloring is reversed, for particularly the ground is in a subdued white or in a light stone color, and the lines thereon are kept in a dark reddish brown. At the east side of the rood screen in the monastery church at Haina a small portion of the plain wall was treated accordingly, so that the sep-

separate stones inclosed by the red lines stand vertically, but with a second line of the same color inside each of them, and in the middle was painted a rosette. In France a similar mode of treamtent is more commonly executed and in part is still richer. An example of this kind from the hall in Angers is found in Verdier. Likewise here are found those isolated ornaments, and there the squaring of the arches is treated with a certain freedom, while the separate stones of the vault are rounded at top. Just on such details is to be laid especial weight, like the vertical position of the ashlars at the rood screen in Haina, the rosettes in them and the isolated ornaments, since these exclude the idea of an intended imitation of actual ashlarswork, which latter was effected by different means and is to be regarded rather as a peculiarity of the modern architectural style. This squared painting in opposition to all such means of deception very simply forms a surface pattern, that at most may be blamed as a lack of invention, but which appears to the untrained eye just as it really is.

We note here, that this extended use of such an effective motive of isolated ornaments may yet lead to misuse. At least we recall having seen an otherwise correct new church in Soissons in the forms of the transition style, whose interior is painted in the given manner, yet concerning those ornaments not much good is to be shown.

Third method of treatment.

The third mode of treatment consists in a further development of the motive already mentioned above, of plants and foliage p painted in natural colors on the whitened surfaces of the compartments, and in an extension of these to the wall surfaces. As such examples we mention:- the choir vaults of the church of S. Elisabeth at Marburg, the later paintings of the castle chapel at Marburg, and the church in Wetter, the monastery church of Breitenau near Cassel, the Liebfrauen church in Treves and the church S. Jacques in Liege.

On the surfaces of the compartments are first found these ornaments, soon more isolated in the manner already indicated on p 633, soon entirely extending over the surfaces, as in the choir at Marburg and the transverse aisle at Wetter, also sometimes intermingled with figure subjects as in Breitenau, where on the choir vaults are found the images if the Holy Trinity, of

the Holy Virgin and of S. Benedict and S. Catherine, but in the middle square are found the symbols of the evangelists inside the given arabesques.

As a rule the stems in the latter are yellowish brown, the l leaves are a bright green and different flowers are painted in other colors, blue, yellow, red and white, yet the latter are sparingly used so that green predominates and its contrast with white determines the effect. In Wetter and Breitenau black or brown outlines are but seldom used, where for crealness they w necessary, briefly where color adjoins color, but not to separate the latter from the white ground. On the contrary in Marburg and likewise in Liege the entire drawing is outlined in black, and indeed in the first place in such a defective manner, that one might almost recognize in it a later addition.

In Wetter the original red painting and the gilding of the relief ornament of the keystone on a dark red ground remained, a and only the mouldings as well as the adjacent parts of the ribs are in various colors without gold, indeed principally in a mode harmonizing with the painting of the compartments, thus painted green, yellow, white, black, etc. Fig. 4 if the colored plate gives an example of this kind.

Similar schollwork, only in larger proportions, was also found on the surfaces of the walls, so that on both sides of the jambs grew shooting stems or stalks from bunches of leaves, ending below in roots and crossing above the windows in arches.

If the attention of men had been attracted to these paintings several decades since, at the time when recognized archaeologists still adhered to the theory of the origin of the Gothic style from the leafy roof of the sacred grove, and even a statue of Ermin von Steinbach was made (indeed only in plaster), as he constructed the pointed arch of two pieces of wickerwork like a basketmaker, perhaps this would have been seen as a proof of that theory, an indication of the profoundest basis of Gothic art expressed in a written cipher.

As we already mentioned on p 630 the simple whitewashing of the suffaces of the walls, each of the modes of treatment explained above also reached its highest ornamentation in certain a actual wall paintings placed even unsymmetrically on suitable places. Thus there is found in the choir at Wetter over the choir stalls the picutre of the Holy Virgin and the Child filling

the entire width of the bay, beneath this being the foundresses of the monastery, Almudis and Digmudis, and there are found vestiges of a contemporary copy of the same picture at reduced scale on one of the crossing piers. In the next bay are then the shields of arms of the elector of Mayence and of Hesse.

The painting of the vaults in the Liebfrauen church at Treves substantially differs from those described above. Here the ground is covered by a yellowish green tone and on this is produced an ashlar pattern by white joint lines. The ribs and keystones are then painted in strong colors and from the latter extends brownish red ornament on the surfaces of the compartments (Fig. 3 of colored plate), and the lower angles between the ribs are painted with white scrollwork with colored flowers. (We shall not omit, that we discovered vestiges of green color on certain scrolls).

We have already designated above the coating of the surfaces of the compartments with a brilliant blue with gold stars scattered over it as corresponding to the highest development of magnificence, that however prescribed a similar splendor of color also for the ribs, rounds, etc., in brief for the parts of the church.

On the French examples mentioned above the treatment of the latter is so bold, that the general effect is still harmonious in spite of the almost too dark tone of the ultramarine. In certain German restorations like the church of S. Stephen at Mayence and the Liebfrauen church in Worms, where the means might fail for a splendid treatment of the whole, the great surfaces partly made it more difficult, and then the pure blue is dulled by the addition of white, so that the golden stars on it appear almost like brass. For this pure smalt would therefore be most suitable.

Meanwhile also in other respects the not very successful Gothic church of S. Eugene in Paris has the surfaces of the compartments coated with yellow, with red stars placed on them, as we have also already found similar experiments on small mediaeval works.

Thus the interior of the wall tabernacle at Wetter is painted in a light seagreen tone with blue stars painted thereon. If then already the original reference to the firmament can be scarcely observed, and the star form is to be regarded only as a

flat pattern, yet it is only one of the simplest and therefore of the most easily employed kinds.

For these varied kinds of experiments of mediaeval polychromy is that new procedure farthest removed, by which for 30 years the whitewashing up to that time was suppressed with the view of putting an end to the monotony thereby produced, and at the same time avoiding the injurious effect of the ground tone on the eyes. This consists in the use of different slightly contrasting yellowish, reddish, bluish and grayish airy tones on the different parts and in its highest splendor rises to gilding certain members or edges, which is naturally entirely without effect in contrast to those broken tones. Particularly common are there the milky blue vaults, the piers, ribs, jambs, etc. With chamois or grayish stone colors, the wall surfaces being painted a softened peach juice, and thus such a dull effect is produced, which by the so-called cultured is usually termed friendly, and that by building officials is sometimes designated as restoring that of the building materials. Most suited to dilettanteism by its indecisiveness, this presents the advantage, that each of the church fathers belonging to the cultured class without consulting an architect could independently give the n necessary directions to the limewasher, and then might enjoy the mild charm of his production. At the present time it is especially favored by certain rationalistic ultras among ecclesiastical and secular officials, who already perceive Catholicism in every decided color. (Note).

Note. Since the preceding words were written, there has been much improvement, the understanding of the old painting has penetrated into extended circles, and many colored works strictly executed in the old sense have originated on German soil. Likewise vestiges of the lod paintings, that indeed everywhere slumber beneath the later whitewash are meantime brought to light in great number. They prove the preceding statements so far, that we hold it to be right to print the latter verbatim in the old form, and to give the most necessary explanations in the succeeding Chapter on the Technics of Paintimg.

2. Technics of Painting in the middle ages.

Adhesives and colors.

The technics of the painting of the middle ages is naturally based on the traditions of antiquity, that were inherited in I

Italy but more in the Byzantine empire. Pliny and Vitruvius, as well as many paintings remaining especially at Pompeii give us information of the skill of the Romans and Greeks. For their mural paintings they appear almost without exception to have employed a well developed fresco method. (Donner, Remaining antique mural Paintings in Regard to Technics). Besides there was also known to them a tempera painting, (Egg and water or fig milk, etc., as adhesive) and an encaustic painting. According to Pliny the latter was not used for walls; the wax colors employed in it appear to have been thickly spread on a ground of wood, etc., with a spatula and then heated, which is unnecessary for our modern fluid wax colors.

Documents concerning mediaeval painting.

In the middle ages the technics were diversified, and there were added oil painting and the preparation of varnishes from vegetable gums melted in oil, etc., and besides was developed the previously well known distemper painting. Besides the art works remaining documentary traditions afford evidence of the methods of painting employed.

The following writings are prominent.

1. Theophilus, priest. Schedula diversarum artium.(see below).

2. Recipes of the monk Dionysius in Handbuch der Malerei from Mt. Athos. German translation by Godehard Schäfer. Treves. 1855. Written in 13 th century with additions until 16 th century.

3. Heraclius. Original text and German translation by Albert Ilg in Quellenschriften für Kunstgeschichte etc., by R. Eitelberger von Edelberg. Vienna. Vol. 4. The date of origin, 11 th to 13 th century, is in dispute.

4. Cennino Cennini. Treatise on painting, published by Albert Ilg in Quellenschriften, vol. 1. Cennino belongs to the school of Giotto and lived at the end of the 14 th century.

Less importance has Petrus of S. Audemar, De coloribus faciendis liber, about 1300, treatise of Alcherius about 1400; writings of anonymous Muratori and Anonymous Bernese (the latter only concerning the preparation of egg albumen, see Appendix to Quellenschriften, etc., Vol. 7.

The most important of these writings is that of Theophilus, who probably lived as monk Rüger in a north German monastery, and describes in the clearest manner not onln painting but also the making of glass and metal works. Copies of the Schedula are

preserved that partly extend back in the 13 th and even the 12th centuries. They are very well edited by Albert Ilg in Quellenschriften, etc. Vol. 7, Vienna. (The added german translation is not entirely satisfactory in places, as for example the expression "illuminare" used for placing the lights is always given as unintelligible.

Painting of books.

Painting on parchment or of books, which may be placed first, is principally a tempera process. The colors are laid with egg albumen, that previously in order that it may not make a wrinkle, is strained through a cloth or better is beaten to foam and must then again be clarified; water is added to it as needed. Beaten egg yolks can also be used, but water and then egg albumen must be added to that it does not scale off.

All colors except white lead, red lead and carmine, that require egg albumen, can also be fixed with gum, i.e., a solution of a vegetable gum (cherry, plum and also resin from needel-leaved trees) in warm water, and also gum arabic was known.

Spanish green, which was employed instead of "Salzgrün (see below) for books, was not fixed with egg albumen, but according to various sources with wine (Theophilus), vinegar, urine or also gum or egg yolk (Cennino). "Folium" (see below) was fixed by urine or egg albumen, and after drying it was painted with folium or carmine with egg albumen (Theophilus, Chap. 40). Gold b bronze or silver was laid on a ground of red lead, vermilion a and egg white or directly on the parchment with gum, a size made of isinglass, leather, eelskin, etc., or also alum, oxgall, etc., was applied and later polished with a tooth or with bloodstone. (Theophilus, Chaps. 29 to 38).

Panel painting in tempera or oil.

Panel painting for the painting of altar panels, doors, ceiling panels, vessels of wood and allied materials with or without a covering of leather or linen is to be considered, and was previously a tempera painting, as just described. Under the designation of tempera painting is best included painting with egg, guml plant gums and allied materials such as honey, milk, beer, etc. Egg, especially in the later time, was mostly thinned with vinegar instead of water, and even with some oil.

Panels were of separate boards well joined together and then glued with strong cement of curd and caustic lime, on this was

cemented leather or linen, then a painting ground of chalk or calcined gypsum with size (boiled from hides or deerskin) was applied several times and then rubbed smooth with equisetum. On this came the color. The chalk ground could also be laid directly on the wood, which especially occurred on curved surfaces. Gold in panel painting and also in mural painting was laid as gold leaf on egg white in one or more layers and was then polished or even painted over.

Oil painting is a species of panel painting, that already was invented very early and probably in Germany, from whence other peoples obtained linseed oil (see Donner, Anmerk. p. 28 to 29). The colors were ground on otone under linseed oil and then often applied with a drying in the sun for several days for each coat (Theophilus, Chap. 20). Finally was applied a varnish made by boiling 2 parts of linseed oil and 1 part gum (Theophilus, Chap. 21). The defect in oil painting was the slow drying, and therefore in rapid work it was replaced by painting uith liquid resin or a solution of gum, which was likewise coated with the varnish above.

Mural painting is most important for us and was in fresco or painting with lime colors, that under some circumstances had t the aid of the tempera process. Colors with size appear to have come less in question.

Fresco painting.

True fresco is well known to be painted with water colors on the fresh plastering, which with a moderate thickness must be only one day old, which requires carrying on the work step by step. The drawing is then sketched lightly on the wall and is then painted; by more accurate work a previously prepared cartoon is placed on the plastering and the outlines are indented with the point. Yet it is not excluded that also without using the cartoon the principal outlines are scratched in to fix them better. Sometimes even surfaces seem to have been sunken deeper, as on the outside of the tympanum of an arcade of the cloister of the cathedral at Stendal, the plastering in the tympanum is enclosed by a triangular band (like that drawn in Fig. 1502 d), whose panels are alternately sunk somewhat and still retain vestiges of red color. A similar arrangement of the plastering is executed for the painting in a very happy at the recently built church of the holy cross in Berlin.

Those wall surfaces were plastered in the interior and also on the exterior, which could not be shown on account of a too irregular appearance; neatly cut stones and the structural members remained without plaster, for arcades and window arches m men were accustomed to leave without passter, but on the jambs the middle strip was to be covered by plaster, when it was not to be made of cut stone on account of louvres. In contrast to the layers of 5 to 8 cm thick of the Romans, the plastering in the middle ages was only so thick as required to conceal the i irregularities. The masonry to be plastered was not usually recessed below the adjacent parts of the same surface remaining without it, and the plastering rather projected for its small thickness (about 1/2 cm) and was beveled at the edges.

Simplified lime painting.

If the painting is to be executed at once, this is done on t the fresh plastering,(See above), but if it is to be done later, then one is aided by a much used and simpler procedure, that is well established. It is sufficiently important to give here verbatim, what Theophilus says of it in Chap. 15 (See Latin text on p. 640 of Vol. II).

The same is more briefly given at the end of Chap. 16; "all colors placed on the wall under others are to be mixed with lime on account of solidity. Under blue "menesh" and green is placed red lead, under vermilion red ochre; beneath ochre and leaves,the same colors mixed with lime."

From this it proceeds that the colors are mixed with milk of lime, and are applied to the previously mointened wall; but such colors that do not bear mixing with lime so well, are laid afterwards by the tempera process on an already dry wall under color.

For capitals and cut stone members the lime colors and even gold are frequently placed directly on the stone, and this also occurs for wall surfaces. But generally after wetting unplastered walls, men first coat them with simple milk of lime and then apply the other fresco colors very quickly on this limewash. On this white ground are found in paintengs from the 13 th to 15 th centuries also without the gray or brown undercoats given by Theophilus, that azure, copper green and vermilion are applied directly, whether freshly on the lime, or after its drying in the manner described by Theophilus with egg yolk and water, is hard to determine. Moreover these three colors also under the

limewashes of later centuries, have kept badly, and the less s suitable colors for the technics of fresco are destroyed. (It is certainly stated for cobalt, that the lime makes it somewhat flatter. Vermilion darkens gradually in the air, yet apparently less with lime than with oil.

Colors suitable for lime painting.

The proper fresco or lime colors, that were approved in antiquity and the middle ages are the following five.

1. Milk of lime (slaked lime and water) was utilized as a white color, as a color for makink the other colors lighter and as an adhesive.

2. Ochre.(iron oxyhydrate mixed with clay) occurs in nature in different tones of yellow.

3. Burnt or red ochre,(iron oxide with more or less mixture) occurs in nature or is obtained from the preceding by heating, which was usual in the middle ages, and was described by Theophilus in Chap. 3. By an adjacent conflagration paintings with y yellow ochre are sometimes burned red. Our English red, iron red, Indian red and caput mortuum are similar products, but the old red was generalhy clearer and brighter than the two last mentioned.

4. Black from charcoal or soot.

5. Green earth (silicate colored by ferrous oxide, terre verde in Cennino), that is known today as Veronese earth, mountain green and stone green, having a broken grayish green tone. To be mentioned here is the Prasinus of Theophilus, that according to Chap. 2 approaches the green and black colors, is not ground on the stone, but is strained through cloth under water, and appears to be very useful as green on a fresh wall. Heraclius (Chap. 37) also indicates a color obtained from mallows with vinegar or wine, which he names earth green es suitable for mural painting.

There are further the following colors previously mentioned. Vermilion, that can even be mixed with lime, and the making of which from sulphur and mercury Theophilus describes in Chap. 41, an animated copper green (yet not Sanish green, see above), the preparation of which is described in Chap. 42 as green salt, a and blue. The latter was mostly copper blue (German blue, Azuro della magna in Cennino), rarely cobalt blue and the very valuable genuine ultra marine (powdered lapis lazuli).

There further appears to be conditionally allowed the purplish color folium, of which three kinds are distinguished by Theophi-

Theophilus in Chap. 40 (red, purple and sapphire) the first of which is made of urine, calcined ashes and caustic lime, the o others are the same without line; they are especially employed in illuminations in books, and according to other statements a are for this purpose fixed with eggs. A color very frequently mentioned by Theophilus is "menesh", which was a broken blue and according to the before mentionned citation was likewise used w with lime colors. The dark sap green was not brought into direct contact with lime, gold pigment and white lead are designated as not to be used for lime pain ing. Red lead according to Cennino becomes dark on the wall, with oil fades with white lead. Theophilus gives as a flesh color determined for tempera in Chap 1, white lead, litharge and vermilion, and that for red parts according to Chap. 4 is composed of some red lead with more vermilion. For mural painting he mixes flesh with lime, o ochre and vermilion (Chap. 15). Perhaps there is a mistake in the mixture of flesh tints (white lead, carmine, etc..), that cause why in old paintings the faces have become entirely white. On the mural paintings in the cathedral of Riga (about 1300) t the colors of the skin have not only bleached under the later plastering, but have so far disappeared, that they do not retain in the painted outlines, and the same is the case for parts of the garments apparently painted with like colors. Very particularly are most organic colors, among which are indigo and a carmine already not permanent in light, are destroyed by lime.

Light and shade, interchange of colors.

Relief treatment of the early period.

The procedure in painting was the following. After scratching in or sketching the outlines on the ground, the principal flat tones were laid beside each other and on these were placed darker and on the other side lighter tones for the shades. The first were obtained by mixing in darker colors, the latter by the addition of lighter colors or of white to the first ground tone. Then the tones were ever laid narrower, until the deepest shade was a dark line of the same color as that with which the outlines were drawn. On the other hand the highest light also mostly extended to a light line that with a light ground tone increased to pure white, but only on darker tones only came to ochre with or without the addition of white, as well as to cobalt blue, g green, flesh red (burnt ochre and white). In Byzantine and Early

Romanesque times men shaded quite in relief according to traditions of antiquity, but still in a conventional way. Theophilus describes in Chaps. 14 to 16 very fully for clothing, other objects and rainbows, and in Chaps. 1 to 13 the very careful treatment of flesh. In this time for all round parts, such as the limbs of men, folds of clothing, trunks of trees, towers, clods offearth and scrolls in ornament, the lights were laid at the middle and then were a series of 4 to 6 or even 12 steps down to the outline color at the edge, and sometimes then went from white through yellow and red or blue, etc., to black; the ground color first laid underneath was then somewhat darker, according to Theophilus it was the 7 th with 12 tones, the 4 th for 6, en the 3 rd place for 5. For 4 or 3 tones the pure color was not the ground tone, but a somewhat lighter step was chosen and on this was laid only one shade tone to the outline. The old paintings prove this.

For objects not round, that it was not desired to leave in o one color, they placed the light at one edge and the dark shade at the other. Thus were shaded also the leaves of Romanesque ornament as indicated in Fig. 1492.

Flatter treatment in middle and later times.

The excessively strong shading in relief is reduced in the t transitional time and makes in the Gothic time a flat painting with moderately strong indication of the shades and lights or indeed also without these. In the last case the painting consists only of uniform tones and outlines, whereby is obtained a very quiet and noble effect and an arrangement of the surface.

An example that the first transition from Romanesque to Gothic modes of treatment very beautifully illustrates, is presented by the painting in the choir square of the cathedral at Brunswick, a portion of which is represented in Figs. 1491 to 1491 b. The ashlars beneath are yellow ochre (apparently changed to light gray, which is elsewhere found for ochre, for example on garments in the cathedral at Riga, where the lights are spared out, the joints being white with brownish red lines at each side. The draperies above are alternately blue, red, green and yellow, the under surfaces visiblae at the lower edge always have the color of the adjacent tapestry. On the ground tone of the drapery lies only a shade tone and a light, (on Fig. 1491 the light lines are dotted) and then come the dark brown outlines, which

are also drawn in the depths of the folds is lines 5 mm wide. In the Gothic time the folds are mostly left entirely without shades, they are indicated in a conventional way by stiff lines, and between each two hollows is placed beneath the point of suspension a fold with a sharp edge drawn as hanging vertically.

In the preceding case the drapery only has an upper decorated edge, and the bottom edge is just marked by a border or fringe. The entire surface usually receives a pattern as shown by Figs. 1503 to 1506.

The tapestry in Brunswick is fastened beneath a blue shaded bar. In a similar manner red and yellow rounds shaded in relief extend above and below the foliage frieze, Fig. 1491 a. The lights of the round are no longer as originally at the middle, but are nearer one edge and are entirely or nearly white. The foliage band has a dark blue ground, the middle leaves are flesh r red, the half leaves are alternately green and blue, the lower trefoil leaves are light violet and the upper ones are yellow. The dark brown outlines are 2 to 3 mm wide and are accompanied by a very effective white line scarcely 2 mm wide (Fig. 1481 a). Stepped tones as in Fig. 1492 are already omitted, only the ribs are broadly placed in a dark color near the ground tone and have at the middle a sharp brown line. Some colors have faded under the later whitewash, but otherwise the ornament shows a refinement in the graduation of the colors and drawing, which is scarcely surpassed by painted ornament in any other style. The treatment of the foliage in relief is abandoned, but a salutary play of the stepped colors is retained.

Treatment of the painted foliage.

Besides the shaded foliage there also occurs in the Romanesque time monochrome foliage, both light on dark ground as well as dark on light ground, and it then assumes a more general character (Figs. 1502 k, 1498, 1493, the latter from the Frankenberg church, at Goslar being reddish brown on a light ground). Gothic foliage is mostly of a single color with dark outlines and ribs. (Figs. 1494 a, 1495). Thereby in the simplest cases were obtained three different colors, one for the leaves (for example green), the second for the scrolls and outlines (for example reddish b brown), and the third for the ground (white, but also blue, violet, dark green, gold, etc.). Greater diversity of colors could be obtained by the occurrence of flowers, berries and accessories,

but still more effectively by varied coloring of the different leaves; thus are distributed on the same scroll light green, dark green, blue, yellowish brown and red leaves.

Another means of securing an animated alternation of colors as a substitute for the earlier shading consists in placing two colors beside each other, for example green and red for the two halves of the lobes of the leaf or of entire leaves (Fig. 1494 b, c). In Fig. 1495 from the church of S. Nicolas at Wiemar the leaves are monochrome, but the branches of grapes are divided between red and green, the leaves and branches have black outlines; the main scrolls are red and the smaller ones are green w without outlines; there the ground of the figures wixed with t the scrolls ascending the high piers as ornaments are formed by a white limewash laid directly on the uneven bricks. In the late time the alternation of two colors often continues regularly through leaves and scrolls as in Fig. 1496, that represents a part of the painting of the vaults of a chapel of the church of S. Nicolai at Juterbogk. Here red and green are contrasted, on other examples are black and green. Black and unbroken yellow ochre generally associate well with the green of Late Gothic scrolls, that combined with great flowers and even figures extend over walls and surfaces of compartments, frequently haveing a rather hard effect in contrast to the earlier foliage. The g ground of these ornaments is mostly white, yet there also occur colored grounds, es in the chapel mentioned at Juterbogk beside white compartments, they are light green with a darg green monochrome ornament.

Softer is the effect of Late Gothic spiral scrollwork in the style of Fig. 1497, it has passed into the Renaissance and was long valued for the covering of the helmets of shields of arms, and frequently occurs also carved on woodwork from the 15 th into the 17 th century. The upper and under surfaces of twisted leaves have different colors, for example green and red or green and blue, besides the colors towere the points of the leaves too frequently pass into another tone, as from light green into dark green or into light brown or red.

Changes in two colors.

The alternation of two equal colors is a motive greatly extended during the middle and late Gothic in heraldry, continuous ornament, in the painting of mouldings and also on a large scale

in the general architecture of interiors, it was possible with small means to obtain a very effective play of color, to which in interiors the concurrence of colored windows led. In a more modest form occurred such a change in all architectural styles. It commenced with repeating two colors rhythmically, as in Figs. 1502 and 1489. Elsewhere already appears in Fig. 1500 and 1501 from the varicolored chapel at Brandenberg an alternation of the ground (red and gray or red and green under the white ornament). But very peculiar is the effect when the colors shift as in Fig. 1499 from the churhc of S. Nicolai at Wiemar, where red and green not only alternate in the halves of the terminal ornament, but are placed on the springings of the ribs and their accompanying scrolls. Men have frequently carried it so far that entire areas of compartments or parts of the walls have been executed with alternation in colors, that for example a compartment with white ornament on red ground alternates with one having red ornament on white ground.

Colors of geometrical ornaments.

No other art section of ancient and modern times has understood how with equally simple means to make possible a satisfactory colored treatment, as the middle ages by its geometrical ornament. With two or three or ever with a single earth color added to lime white, an interior was treated with comparative r richness and always harmoniously by means of the simplicity of colors.

Red ochre alone.

The most important color was burnt ochre. It exhibits when p pure or mixed with a little lime a strong and quiet red, that sometimes passes into brown, but more commonly is so fiery, that an untrained eye sees in it a mixture of vermilion and carmine. (In the works of restoration in the cathedral at Riga it was found difficult to find a modern iron oxide of equal brightness). With more milk of lime red ochre gives pleasing rosy tones. With this simple color in different grades and with white may indeed an architectural part be decorated, or even in entire interior; Figs. 15 and 16 as well as Fig. 14 on the colored plate will allow thes to plainly appear.

Red ochre and black.

If a second color be added, whether yellow ochre or black, t there is often a great diversity of tones. A beautiful example

for a painting with two colors, red and black, is presented by the cloister at Riga built at the beginning of the 13 th century (Figs. 1480 to 1485).

+esides the white with the aid of burnt ochre produces a full red and a lighter flesh red (hatched vertically on black in the sketches) and with soot or charcoal black are formed two gray tones (hatched horizontally), the lighter of which mixed with much lime gives a quiet stone gray, that on the contrary the darker is a dark slate gray, and the latter has an expressed t tendency to blue, always resulting from a mixture of black and lime. On the Figs. it may be noted, that Fig. 1480 represents a cross arch, Figs. 1481 and 1482 are the crossing of two round or polygonal ribs, and Figs. 1483 to 1485 are the round extending around the openings of the arcade.

An entirely similar character is borne by the undersides of the cross arches from the variegated chapel at Brandenberg given in Figs. 1486 and 1487, which belong to the original painting. Placing red and gray tones beside each other is very common during early and middle Gothic, and with gray tones not infrequently occurs pure black, as on the recently painted columns of t the chapter hall at Walkenried, on which the colors are distributed about according to the mode of Fig. 1489.

Red and yellow ochre.

Still more effective and warmer are the gradations -- and also in the mextures in the given cases of the two colors; yellow a and red ochres. Paintings executed with only these two colors and white are especially found in the transition time and often in Early Gothic. On the colored plate, Figs. 2, 7, 12 and 14 c chiefly or exclusively exhibit these colors, and Viollet-le-Duc also gives beautiful examples. (Dict. Vol. VII, p. 83 to 89).

The preceding colors and earth green.

The same occurrence of the three colors, yellow, red and gray or black is also certainly as complete, and there is also added the more rarely employed earth green, very good in those tones that can represent green. Moreover also ochre and black has a rather greenish tone; since further dark gray inclines to blue, one does not miss the green and blue colors in the use of only the three principal colors.

Outlines.

Paintings with these simple earth colors are always very quiet

and harmonious, and it is scarcely possible to form with them a glaring composition, therefore they do not need also a separation by outlines, which in fact are almost never employed with them.

In regard to the outlines and the lines drawn elsewhere on t the surface it may be stated, that in the early time and also frequently in the middle Gothic, men with refined feeling mixed the color tone of the lines as a darker stage of the corresponding ground tone as Theophilus prescribed. Later appear more uniformly colored lines of dark brown (brown ochre and black) or blacker color.

Rich colors and gold.

An entirely different charcater is assumed by painting, when there occur the animated colors, vermilion red, copper green and azure or cobalt blue, and eventually other tones. It is then only necessary to add the gleaming gold, or as in the chapel of S. Katherine and the cross chapel of castle Karlstein, even precious stones and glass bits underlaid by gold to develop the greatest splendor conceivable. That the gold would be imperatively required by animated blue as Viollet-le-Duc asserts, we m might not emphasize in such decided manner, with reference to many examples.

That this rich treatment is restricted to preferred points or can be extended over the entire interior is more fully stated in the preceding Chapter, and to add to the examples there given is unfortunately impossible with the space otherwise exceeded (Note), and we must be satisfied though unwillingly, by compressing in two plates a number of sketches in Schematic representations.

Note. Therefore reference is made to the first not extensive but for the time very well worthy of consideration, the literature on ornamental painting. 1. Viollet-le-Duc. Dict. Art. Peinture. 2. A. Schäfer. Gotische Wandmalerei zu Marburg. Deut. Bauz. 1876. p. 324. Same, gotische Zimmermalerei aus Fritzlar, Zeit.f. Bauw. 1881. 3. Essenwein, Martinikirche zu Köln, Organ f. christ. Kunst; same, cathedral at Braunschweig. 4. Steinbrecht, Hochschloss zu Marienburg, Cent d. Bauw. 1885. Moreover are scattered statements in inventories and architectlura monuments. Further works with plates. Aus'm WWerth, Wandmalerei des Mittelalters in den Rheinlanden. Ungevitter, Ornamentik (unfinished). Mural pain-

paintings in S. Chapelle at Paris, Mural Paintings of Notre Dame at Paris, etc.

Optacal illusions.

To the plates are also added Figs. 1488 to 1490, that show g geometrical motives on shafts of columns and of rounds. For these it should not be omitted, that the rope pattern (Fig. 1489, bottom) can easily produce an optical illusion of an oblique position of the column, and this in some circumstances can occur on a great chevron pattern, and the latter can further cause an apparent diminution of the column upward or downward according to the point of sight. Great patterns like that of Fig. 1487, which frequenlty occur, may produce enlargements or reductions or wavy outlines. patterns like Fig. 1490 are little or not at all affected by such illusions (also see on p. 587). Such illusions are not serious in themselves, but on the contrary they serve to animate and to arouse a too rigid quiet; they are likewise not foreign to Greek architecture, where it is only on many kinds of frets, especially an unexpected wave line (running dog), and there are even found well known twisted Doric columns. Moreover it is entirely required to properly use this powerful means, since a frivolous or unknown play with them instead of animation may produce the impression of unrest or even of anxiety, gust as does the new painting of certain churches.

Window enclosures, bands and borders.

With the sketch in Fig. 1498, which represents the enclosure of a window of the church of S. Katherine only remains in small fragments at Riga, let the note be joined, that very often such scrolls extend on door and window arches, that are formed like the scrolls accompanying the ribs in Figs. 1490 and Fig. 11 of the colored plate, and frequently terminate above the vertex of the arch in richer leaf or flower crownings.

Wall patterns.

Fig. 1502 exhibits borders and bands of different periods, t that are found in most varied repetition on members of vaults, cornices, painted tapestries, jambs, vessels, etc. The peculiar border in Fig. 1502 a very frequently occurred in Byzantine b buildings, and larries its origin back to borders of clothing with precious stones. Likewise the wall pattern in Fig. 1503 already occurs in Early Christian times (baptistery nf Orthodox, Ravenna). Stars, rosettes and crosses as shown in the most dif-

different forms in Figs. 1504 and 1505 are never enclosed by l lines, but often extend independently on the surface; the same is true of the richer forms in Fig. 1506.

Figure ornament.

Fig. 1507 is a portion of the genealogical tree of Christ discovered in the former vestibule of Riga cathedral, which represents an example for the interweaving of ornament and figures, which frequently occurs in Romanesque buildings in a far more complex manner, and has found its place especially under broad dividing arches. Likewise on continued friezes and entire surfaces of walls in the early and late periods men and animals are not rarely inserted in foliage. Unfortunately the figure painting must remain excluded from our consideration.

Painting on the exterior.

In conclusion reference may be made to this, that also on the external surfaces of buildings occurred paintings, that are like those of the interiors; they are employed to characterize preferred parts like the portals or passages, or to elevate an entire wall surface, which does not appear in naked form. Likewise on brick buildings occurs painting, aside from glazing, it finds there its particular place on the plastered friezes and blind arches, and is still often preserved.

Mosaic pictures are rare in Germany, among which the relief figure of S. Maria on the castle chapel at Marienburg occupies the most prominent place, but are naturally the most monumental expression of external painting.

Mistakes in restorations.

In the restoration of mediaeval buildings the ornamental painting is usually entirely neglected or spoiled, and the figure painting is also very badly treated. Might men then finally desist from repairing as quickly as possible the uncovered paintings, instead of simply restorong them somewhat in the injured and lacking parts, or where the locality permits, to leave them entirely untouched. If however all must be painted anew, one m might seek means to copy faithfully the discovered painting on linen, stretching this over the old. At least then the old painting is not irrecoverably lost for research, which is the case by repainting by the best artists, since posterity can never have proof of the conscientiousness of the work. In every case men should never touch a painting without examining its technics

and copying in very detailed form in its condition as found.

CONCLUSION. (Unchanged in this edition).

The most acute perception of the conditions to be fulfilled, the given proportions and the peculiarities of the materials, the endeavor ever to attain the greatest aims with the smallest means, but first of all the conscientions fear of any untruth in the development of form and the avoidance thereby required of all substatutes, are characteristic peculiarities of Gothic construction. Even the frequently occurring conpeftion according to the worst works of Late Gothic partakes of these, and sins only by a certain overloading, a splitting of hairs dangerous to every principal.

In no less measure are those peculiarities also those of Greek architecture, so that the full diversity of the results is even based on the difference in conditions and materials, as well as further in the era and the course of development of Gothic art, whereby this was placed in condition to develop the results of all preceding art epochs, thus also of those following the Grecian, into its own system.

Herein in the traditional character of Gothic art, in its thoroughly preserved historicity, lies a second and no less important impulse of it, whereby it differs not so much from the Renaissance and the Rococo as from a certain tendency of modern a aims in art, which proceeds there to the invention of a novel and contemporaneous architectural style by means of an entirely capricious mixture of all preceding on the vehicle of the substitute. Instead of assimilating the principles of the preceding styles, men thus secretly try its results, instead of using the materials belonging to the modern period like cast iron, which possesses really valuable qualities, and using it according to them, seeking to develop a corresponding form, it is employed entirely as an imitative material for the display of a richness foreign to the entire construction, it is cast into shapes entirely contrary to its properties, in brief men seek to attain thereby a free artistic activity, that entirely excludes all capacity of understanding and even all deeper study.

Concerning this free artistic activity, there is now a quite conceivable thing. Whatever a titanic individual may give or has given, according to the preceding and to unite at once the

elements of the earlier into an entirely new whole, and thus m make almost a real fact, it is still the belief, that it belongs in this category to regard every single one as a misfortune. But for all natures planned on a smaller scale, the only way to artistic freedom is only through a careful study of the preceding art periods, to find by conscientious research their structural principles, and therefore since Gothic architecture in a sense represents the conclusion and product of all primary periods of art, first in the study of the latter. May it be in the result in these pages to make easier such endeavors.

The End.

1895

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